



POLICIES FOR IMPROVING QUALITY IN SUPPLY CHAIN

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Policies for Improving Quality in Supply Chain

Abstract:

This paper is aimed to analyse the problem associated with quality in a two-stage supply chain with one supplier and one manufacturer. Most cases in real life is not this simple, although for the propose of keeping easy for calculations, even if there're several suppliers we can simplify it to only one supplier that provides different quality level products. A mathematic model is built to simulate the problem and we will analyse the problem into two real cases, which will be detailed in the paper. Finally, we aimed to get some conclusions from these cases.

1. Introduction

Suppliers and manufacturers face a daily complex task of supervising the quality of raw material or components in their production lines. At supplier's level, this task might vary from controlling how much pesticide being used to grow the raw material to how well performed is one special technique used to extract this material. At Manufacture's level, the task of quality control consists of, apart from ensuring minimum standard for raw material bought from suppliers, guaranteeing suitable environment for storing the raw material and half made products, assuring the correct assemble process, avoiding vary kinds of contamination...

Quality can imply different cost depending on which are the requirements of the final customers, the selling price, the impact that will result on manufacture's and supplier's level if a failed final product reach to a customer, the cost to destroy a half-made product or re-manufacture it when detecting quality failure and other kinds of consequences.

Depending on each company's long and short-term goals, they apply different strategies for quality control. And therefore effort invested into checking the right standard of product can differ. But when signing a contract between supplier and manufacture, there should exist some clauses that limits the minimum effort invested from each parts. So, how much effort should be invested from supplier level and how much from the manufacturer's? Moreover, if one failed product reached to a costumer, which can have consequences as product recall, business interruption or reputation damage for both manufacturer and supplier, who is responsible for what percentage of the overall damage?

In this paper we are giving two practical examples in which this two stage model can be applied. The first of them is a very simple, authentically one supplier and one manufacturer that produce one final product and then sell it either to retailer or final costumer. It is about a wine making company named Sutter Home Winery, which had some serious quality problem on its level of arsenics contained in their bottles (see case 1). The second example given is a multiple stage supply chain which manufactures one final product, requiring multiple components, each of them provided by different suppliers. In this case, we choose two consequent stages within this multiple stage supply chain and consider the next stage as our final costumer. In addition, we simplify the multiple supplier as one supplier that provides on key component of diverse standards in quality (see case 2).

Case 1:

Sutter Home Winery is one of the largest family-run independent wineries in the United States. It is located in California and they sell wine under twenty other labels including Newman's Own and Folie à Deux. Currently, their annual production is about 20 million cases with Sutter Home White Zinfandel making up a good percent of the sales.

Recently, a piece of news published by CNN on the 29th of March 2015 raised public concern about its high level of content of arsenic in their products, among other brand of cheap Californian wine. [1]

Here is a list of wines that are claimed to have high levels of arsenic, as high as 500% higher than what is considered acceptable by U.S. Food and Drug Administration Standards. The following list shows the brand names of contaminated wines: Sutter Home Sauvignon Blanc 2010, Sutter Home Gewurztraminer 2011, Sutter Home Pink Moscato, Sutter Home Pinot Grigio 2011, Sutter Home Moscato, Sutter Home Chenin Blanc 2011, Sutter Home Sweet Red 2010, Sutter Home Riesling 2011, Sutter Home White Merlot 2011, Sutter Home Merlot 2011, Sutter Home White Zinfandel 2011, Sutter Home White Zinfandel 2012, Sutter Home Zinfandel 2010

Inorganic arsenic has been classified as a human carcinogen by the Environmental Protection Agency. It is naturally occurring in the air, soil, and water. These natural factors, in turn, have an unpredictable effect on the levels of arsenic in many foods and beverages. In the case of wine, grape is the main raw material and it can naturally contain some level of arsenic depending on the soil that has been cultivated and the pesticide or water used during its growing process. All these factors together build in the risk at supplier's level and effort must be invested for checking the level of contamination.

But also, in the manufacture process, the possibility of contamination increase as the winemaking process progresses as well as arsenic contamination changes

can occur during fermentation. Moreover, other kind of contamination can also occur during this process, such as chemical residuals left after fermentation by bacteria, which can also be damaging to consumer's health. These factors construct the risk at manufacture's level, which is independent of the risk in supplier's level. However, when it comes to determine the effort needed to fulfill minimum quality standards, the manufacturer will always chose own effort level after observing supplier's effort.

Once the contaminated wine reaches to the client, in other words, contaminated product has not been noticed by the supplier or manufacturer, as this case has evidenced, both manufacturer and supplier have severe consequences, such as cost of product recall, reputation damage, loss of sales...

(see Annex 1)

Case 2:

On the 25th of August 2014, Apple announced a recall program for their sold units of iPhone 5 between September 2012 and January 2013. The recall offered to replace batteries for free after receiving a huge amount of complains from their customers. "The sold units experienced a shorter battery life or needed to be charged more frequently", as Apple phrase it. [2]

Battery life durability is a key feature when choosing a smartphone for nowadays costumers. But even such a popular and successful company as Apple struggles to reach the quality required for their products.

There are several suppliers for Apple's product, some of them publicly known, for instance Samsung SDI, Amperex Technology Limited and Tianjin Lishen Battery. But we have no trustful information about which are the companies providing iPhone 5's batteries, since this is confidential information. Nevertheless, we know that the recall program mentioned before should be a shared responsibility both for Apple's company and the suppliers. Then what percent of responsibility assumed each part?

This case can be simulated into a two-stage supply chain. Let's simplify the several suppliers as only one supplier that needs to meet Apple's specifications for its iPhone5. Then once batteries are provided, Apple's factories assembles the final product by combining the battery and other components (which are not included in this study). At manufacture's level, there is also a risk of not assembling the battery at the right way or may the software implemented not be efficient and therefore causes a quick drain of battery.

Once the failed batteries reaches to the costumer, consequences must be hold by supplier and manufacturer. For this example, Apple lost reputation for their image of supreme quality, lost trust from their customers, had to promote a recall program and dealt with sales lost. Supplier may had to remunerate part of the recall program, assume part of sale lost and take up lost reputation for

other customers or Apple's future orders. These consequences must be taken into account when formulating a contract; penalization and responsibilities for each part should be clearly stipulated for the best of both parts. (see annex 2)

2. Literature Review

Quality can be improved in this two-stage model through two methods: *supplier selection* and cost penalties. The first is not included in this study, since we suppose in our case that this selection has already been carried out. The second, *cost penalties* forces the involved parts, both supplier and manufacture, to fulfil the according terms specified in contract and satisfy the customers' requirements. Therefore the main objective in this paper is to study how to sign a quality-sensitive contract with cost penalty between the supplier and manufacturer.

There exist significant and growing amount of literature about of quality in supply chain. If quality in products is not specified in clear clauses, suppliers may attempt to supply substandard products (Friedman [3], 1986; Fudenberg and Tirole, 1991[4]; Moulin, 1995[5]).

After firms started to detail quality terms in their contracts with suppliers, there has been a growing interest and studies about how to improve quality in supply chains. Reyniers and Tapiero, 1995 [6], study the risk and impact of strategic quality control, both in a cooperative and non-cooperative game, which implies the motivation and preferences of each of the parties. The crucial advantage of according terms of quality in a contract is to protect both parties by reducing uncertainty and stabilize their respective production environment. Tagaras and Lee,

1996[7], explore the relationship between the suppliers quality input and the imperfections of the manufacturing process. This may involve contracts to bind both implying parts to deliver products of 'acceptable' quality and reduce uncertainty. Starbird [8], 1997 studies the effect of the buyer's level of inspection on the supplier's quality level. Baiman et al. [9], 2000, analyse the relation between product quality, the cost of quality and the information available for each part when signing a contract, in which the supplier is responsible for prevention cost of selling defective products and the manufacturer or buyer is responsible for appraisal cost to identify defects.

Starbird [10], 2001 extended his previous study to the effect of penalties, rewards and inspection policies on the behaviours of a cost minimizing supplier. Kashi R. Balachandran, Suresh Radhakrishnan [11], 2005, examine contract's penalty/warranty terms based on incoming inspection and external failure information. Kaijie Zhu, Rachel Q. Zhang, Fugee Tsung [12], 2007, study the quality-improvement interaction with the operational-decisions and explores the role of different parties in quality-improvement. Tapiero and Kogan [13], 2007, prolonged Reyniers and Tapiero 1995 by providing a comparative and economic approach to strategic quality control in a supply chain.

3. Model

We study a two-stage serial supply chain with one manufacturer and one supplier. The manufacturer purchases a key raw material from the supplier and converts it into a final product that is sold to resellers or end customers. There is a risk of quality failure (i.e., contamination) in the chain and this represents health consequences for the public when a contaminated product reaches the end customer. Let r_s denote the probability of a contamination at the supplier level. Any contaminated item that has been undetected by the supplier is passed to the manufacturer. Independent of the supplier's contamination risk, the product may be contaminated at the manufacturer's level with probability r_m .

Both the supplier and the manufacturer may exert costly efforts for quality control and inspection. Let $e_s \geq 0$ denote the supplier's effort level and $e_m \geq 0$ denote the manufacturer's effort level. For simplicity, we assume that the cost of quality control is linear in the effort level, that is, $c_s e_s$ and $c_m e_m$, where c_s and c_m can be considered as the marginal quality control cost. We map the effort level to the success rate of contamination detection with a function $p(\cdot)$ such that $p(0) = 0$, $p'(e) > 0$, $p''(e) < 0$ and $P(e) \rightarrow 1$ when $e \rightarrow \infty$. In particular, we assume that the probability the supplier detects a contaminated item is $p_s(e_s) = e_s/(e_s + 1)$, and that the manufacturer's detection probability function is $p_m(e_m) = e_m/(e_m + 1)$. Assuming 100% inspection rate or equivalently assuming that a single product flows through the supply chain, the probability of a public health threat can be calculated as follows: $p(e_s, e_m) = r_s(1 - p_s(e_s))(1 - p_m(e_m)) + (1 - r_s)r_m(1 - p_m(e_m))$. We assume that the public welfare cost associated with such an event is P , which could include costs such product recall, business interruption, and reputation damage. When a contaminated item is detected in the chain, it is destructed at a per-unit cost of d_s or d_m depending on whether the item is detected by the supplier or the manufacturer. Due to value-adding operations, we assume it is less costly to destruct a component than a final product, that is, $d_s \leq d_m$.

For illustration, suppose the supplier incurs $k \times 100\%$ of the public health threat cost P while the manufacturer's share is $(1 - k) = k \times 100\%$. Here, k is assumed to be an exogenous parameter which might be determined via a previously negotiated contract. For $k > 0$, we assume that $kP > d_m$ and $kP > d_s$. Suppose also that destruction costs are incurred by the agent who detects the contamination. Then, the total costs of the supplier and the manufacturer include quality control cost, destruction cost, and own share of the public welfare cost.

$$C_m(e_m, e_s) = c_m e_m + p(e_s, e_m)kP + [r_s(1 - p_s(e_s))p_m(e_m) + (1 - r_s)r_m p_m(e_m)]d_m \quad (1)$$

$$C_s(e_s, e_m) = c_s e_s + p(e_s, e_m) k P + r_s p_s(e_s) d_s \quad (2)$$

In a decentralized chain where members make their effort level decisions independently, if an agent is not responsible for any portion of P , that is $k = 0$ or $k = 1$, then that agent's optimal decision will be to exert no effort in quality control.

3.1 List of variables

As follow there is a clear list of variables with its units:

- r_s : Probability of contamination at the supplier level (% units of a batch)
- r_m : Probability of contamination at manufacturer's level (% units of a batch)
- e_s : Supplier's effort level (supervised units of a batch)
- e_m : Manufacturer's effort level (supervised units of a batch)
- c_s : Marginal quality control cost at supplier's level (\$ per unit)
- c_m : Marginal quality control cost at manufacture's level (\$ per unit)
- $p(.)$: Rate of contamination detection (% of units per batch)
- d_s : Destructed unit cost at supplier's level (\$ per unit destructed at supplier's level)
- d_m : Destructed unit cost at manufacturer's level (\$ per unit destructed at manufacturer's level)
- P : Public health threat cost (\$ per contaminated unit that reached to customer)
- C_m : Total quality control at manufacturer's level (\$ per batch)
- C_s : Total quality control at supplier's level (\$ per batch)
- k : Parameter of responsibility if a contaminated item reached to customer ($k \times \%$ for supplier and $(1-k)$ for manufacturer)

There are several issues that need to be addressed before starting to solve this problem numerically. First, we need to give an initialling value for each fixes variables, which evidently can vary for different cases. In this paper we only simulating for the two cases exposed above, the winery and iPhone 5 case. Second, we suppose that in all the cases being studies the batch size is 100 units, this is due to the fact that we defined p , the rate of contamination detection the following properties: $p(0) = 0$, $p'(e) > 0$, $p''(e) < 0$ and $p(e) \rightarrow 1$ when $e \rightarrow \infty$. It is not realistic to fix effort level infinite, each batch has a determined size, so we fix it to 100, this make our supposition pretty close to $(e) \cong p(100) \rightarrow 1$.

3.2. Sharing Public Welfare Cost

When it comes to sign a contract between two parts, in this case the supplier and the manufacturer, there must be a term in which responsibility for Public Welfare Cost must be clearly divided. In this mathematical model that we try to simulate, the term is represented by the parameter k . When a contaminated product reached to a

customer, consequences of it which we denominate Public health threat cost P must be shared between the two participant parts. But what % is a fair distribution? And once k is fixed in the contract, what's the optimal, minimal quality cost for each side?

3.2.1. Supplier leads the quality efforts

In the first model, assume that the supplier acts as the leader and makes the effort level decision e_s ; next, the manufacturer chooses own effort level e_m after observing e_s . For a given e_s , the manufacturer solves the problem $\min_{e_m \geq 0} C_m(e_m, e_s)$ where the cost function is given in (1) and determines best response function, $e_m^b(e_s)$. Anticipating the manufacturer's best response, the supplier solves the problem $\min_{e_s \geq 0} C_s(e_s, e_m^b(e_s))$ where the cost function is given in (2). Then, (e_s^*, e_m^*) constitute a subgame perfect Nash equilibrium pair if and only if $e_s^* = \operatorname{argmin}_{e_s \geq 0} C_s(e_s, e_m^b(e_s))$ and $e_m^* = e_m^b(e_s^*) = \operatorname{argmin}_{e_m \geq 0} C_m(e_m, e_s^*)$.

3.2.2. Manufacturer leads the quality efforts

In the second model, assume that the manufacturer acts as the leader and makes the effort level decision e_m ; next, the supplier chooses own effort level e_s after observing e_m . For a given e_m , the supplier solves the problem $\min_{e_s \geq 0} C_s(e_s, e_m)$ where the cost function is given in (2) and determines best response function, $e_s^b(e_m)$. Anticipating the manufacturer's best response, the supplier solves the problem $\min_{e_m \geq 0} C_m(e_m, e_s^b(e_m))$ where the cost function is given in (1). Then, (e_s^*, e_m^*) constitute a subgame perfect Nash equilibrium pair if and only if $e_s^* = \operatorname{argmin}_{e_s \geq 0} C_s(e_s, e_m^b(e_s))$ and $e_m^* = e_m^b(e_s^*) = \operatorname{argmin}_{e_m \geq 0} C_m(e_m, e_s^*)$.

4. Numerical simulation

The model is simulated with the program Matlab and plotted in 3D with the following parameters, which are a rough estimation of the real case. For instance, we suppose that inheriting risk at supplier's level is about 5% and in the winery case, the risk at manufacturer's is higher (3%) than the risk at Apple company since Apple has better automatic control of all the processes, which means that it has lower standard deviations in quality. The cost of quality control per unit is estimated thought the selling price of the final product and its standard of expected quality. The same is applied to destruction cost and public wealth threat cost.

The numerical data applied to each case might not be very accurate, but since this model can be applied to most products and cost and prices vary depending on the place of production, company's policy, time, etc. The results obtained in this paper and the simulations done is just some examples to illustrate the utility of this model.

On Annex 3 you can find the Matlab program that we built in order to make all the simulations showed below.

Winery case

parameter	Value	Unit
r_s	0.05	% units of a batch
r_m	0.02	% units of a batch
c_s	0.05	\$ per unit
c_m	0.08	\$ per unit
d_s	0.10	\$ per unit destroyed at supplier's level
d_m	0.20	\$ per unit destroyed at manufacturer's level
P	1000	\$ per contaminated unit that reached to customer

If $k=0$

For k equals to zero, meaning that if supplier does not incur in the sharing of responsibility of health threat cost, it seems obvious that the supplier part will not make any effort in quality control. The values of the parameters are estimate according to the selling price of a bottle of cheap wine, which is the case exposed. We are here estimating that one bottle of Californian wine is averagely sold at the price of 1,5 US\$, therefore the total cost of a batch of 100 wine should not cost more than 100 US\$ accounting supplier's plus manufacture's cost. Checking on the grafts below, resulting from simulating the model, we can see and we expected that no quality control would cost more money for the manufacturer. Since supplier has no responsibility on public threat cost, it is obvious to expect that this part will do no control, therefore manufacturer will suppose e_s equals to zero.

Assuming that our model is right, manufacturer would decide to do quality control only under the permission of having a profit on its product.

So, if quality cost exceed the 15% of total cost of the product, which means 15 US dollars per batch invested in quality it makes no sense in this business. As we can see in the Figure 1, the lowest cost hold by manufacturing part in quality is around 20 US dollars per batch, this conclusion is non-sense to manufacturing part. For $k=0$, manufacturing part will not sign any contract with the supplier, unless the public health cost per unit P is very low comparatively to the quality control cost, which in this case should not be higher than 200 US dollars.

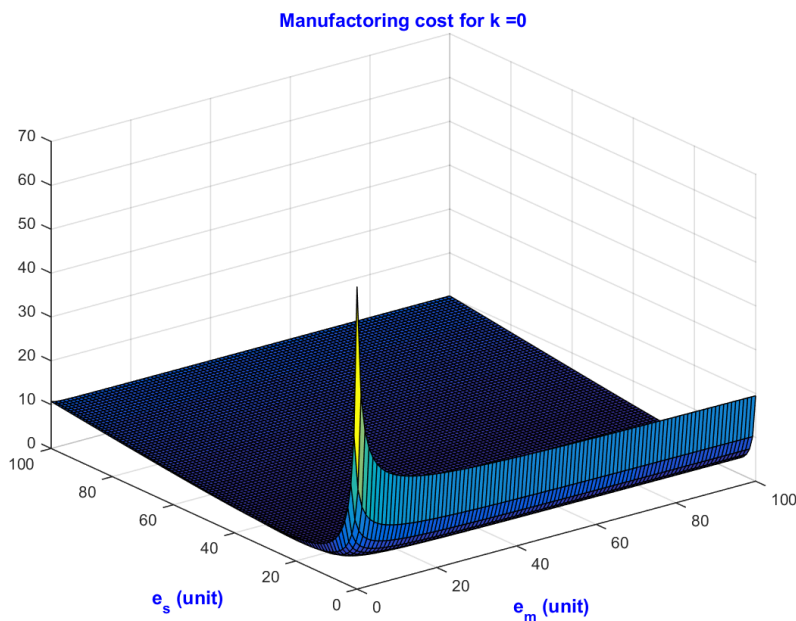


Figure 1 manufacturer's total control cost at $k=0$

At supplier's part, if $k=0$ this part have no interest in guessing what will be manufacturer's response as it has no responsibility to take. It will automatically skip control to invest as little as possible in quality, but the consequence of it may not be favourable to him, if manufacturer part decide to not collaborate with supplier's part. But this is an issue not being studied in this paper. Below, in the figure 2 is shown the total control cost assumed by supplier, as it can be expected is much lower compared to manufacturers. Even it can reach to no cost, however this might not be a realistic case to suppose k equals to zero.

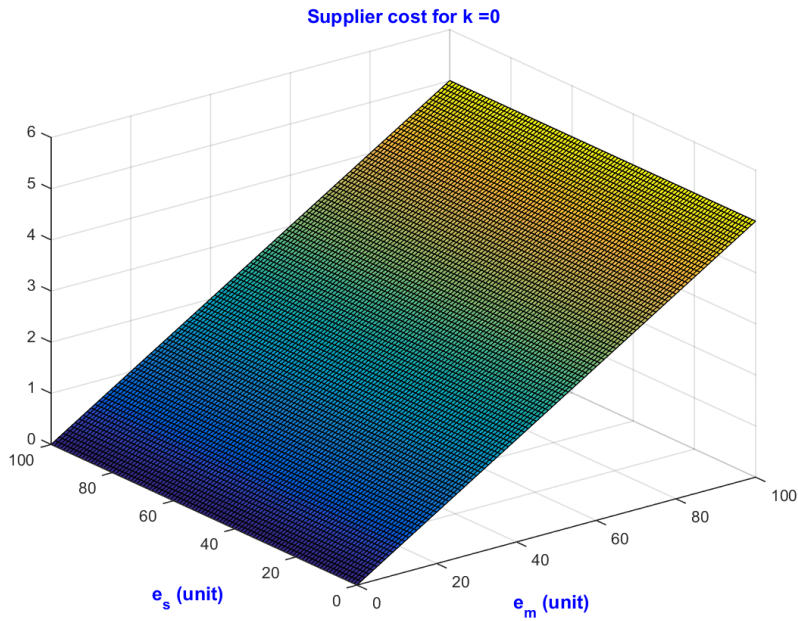


Figure 2 supplier's total control cost at $k=0$

IF $k=0.5$

If responsibility is shared at the same proportion between supplier and manufacturer. At the manufacturer's part, assuming the best response of the supplier which is to do an effort of checking 18.6% it's supplied raw material, seeing the results of cost function, manufacturer will decide to do an effort of 9.64% which matches to the minimum total cost of 3.85 US dollars per batch. This is a cost that is perfectly assumable by manufacturer and it is realistic.

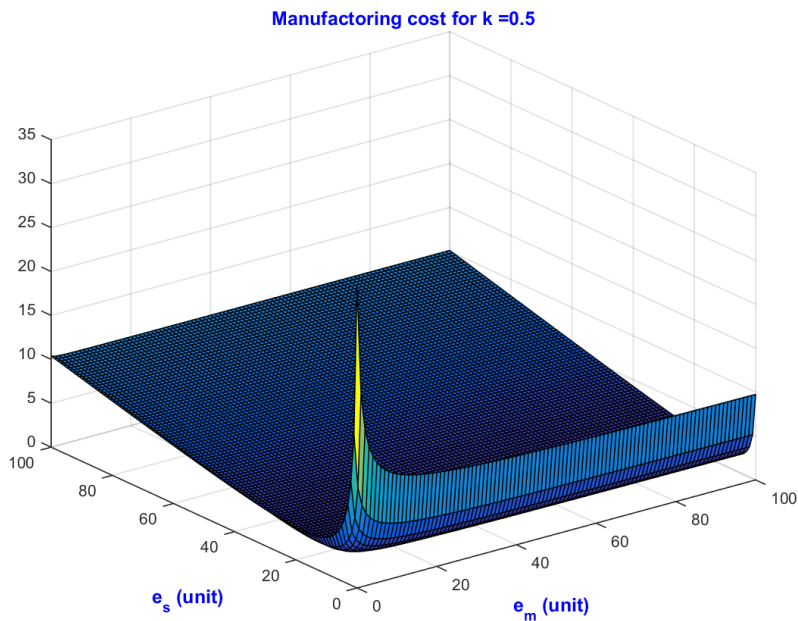


Figure 3 Manufacturer's total control cost at $k=0.5$

Similarly, for an equal share of responsibility, supplier's control cost depends on the manufacturer's effort. In the supplier's total control cost model, if manufacturer's best response is expected, which in this case is $e_m=8.71\%$, the relative lowest total control cost for supplier is 3.45 US dollars per batch with an effort of $e_s=11.32\%$.

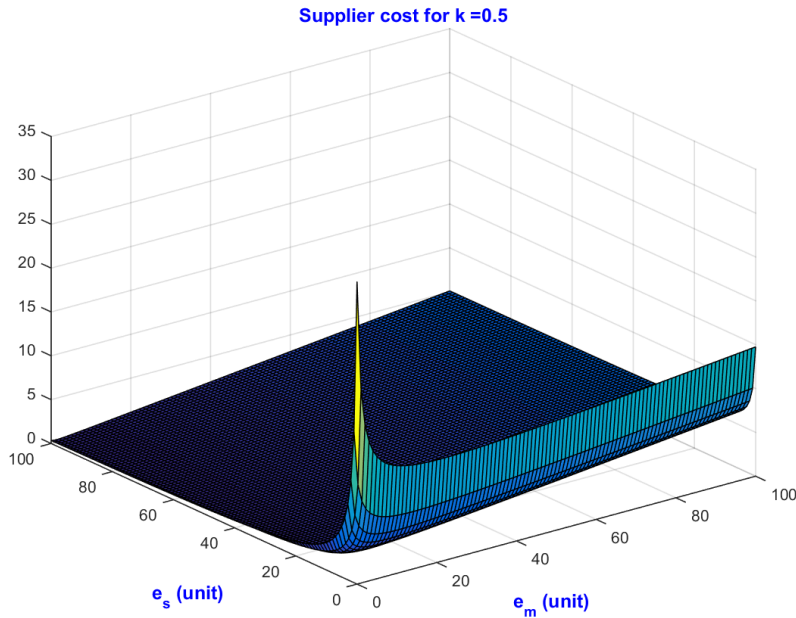


figure 4 Supplier's total control cost at $k=0.5$

If $k=1$

The result for this simulation is exactly inversely equal to the case of $k=0$, but the major control cost is assumed by the supplier. It is, as well as the case of $k=0$, unrealistic to happen in reality, since no enterprise would invest more in quality than its profit margin. The minimum cost requires for the supplier is around 25 US dollars per batch and we are supposing that total selling price for supplier's raw material is around 20 US dollars. Obviously, this is only a case to study in theory. (see graphics in annex 4)

Optimal k for minimal total control cost in both levels

In order to find the optimal total cost for both supplier and manufacturer, being the perfect couple of effort applied by each level e_s^*, e_m^* , we have simulated through the model with Matlab with a k_step equal to 0.1 (see simulations in Annex 4). We found out that the perfect couple can be found at the agreement level of $k=0.64$. In this case of Winery, optimal effort in control at supplier level would be $e_s^* = 14,32\%$ and $e_m^* = 14,74$, which means a total control cost of 1,66 US dollar per batch for the supplier and a total cost of 1,75 US dollars per batch for the manufacturer.

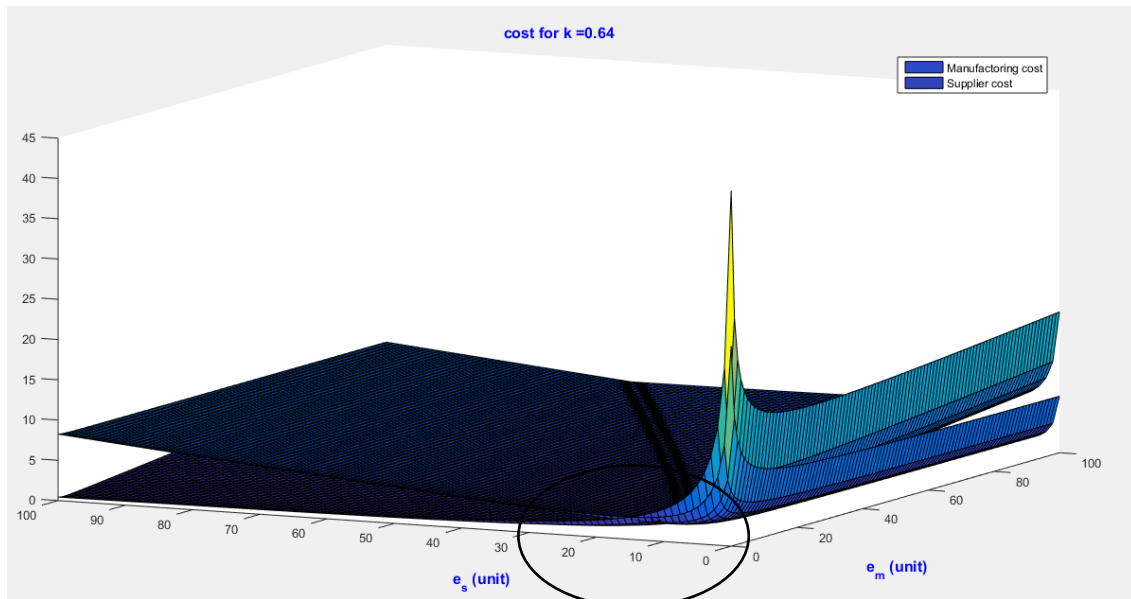
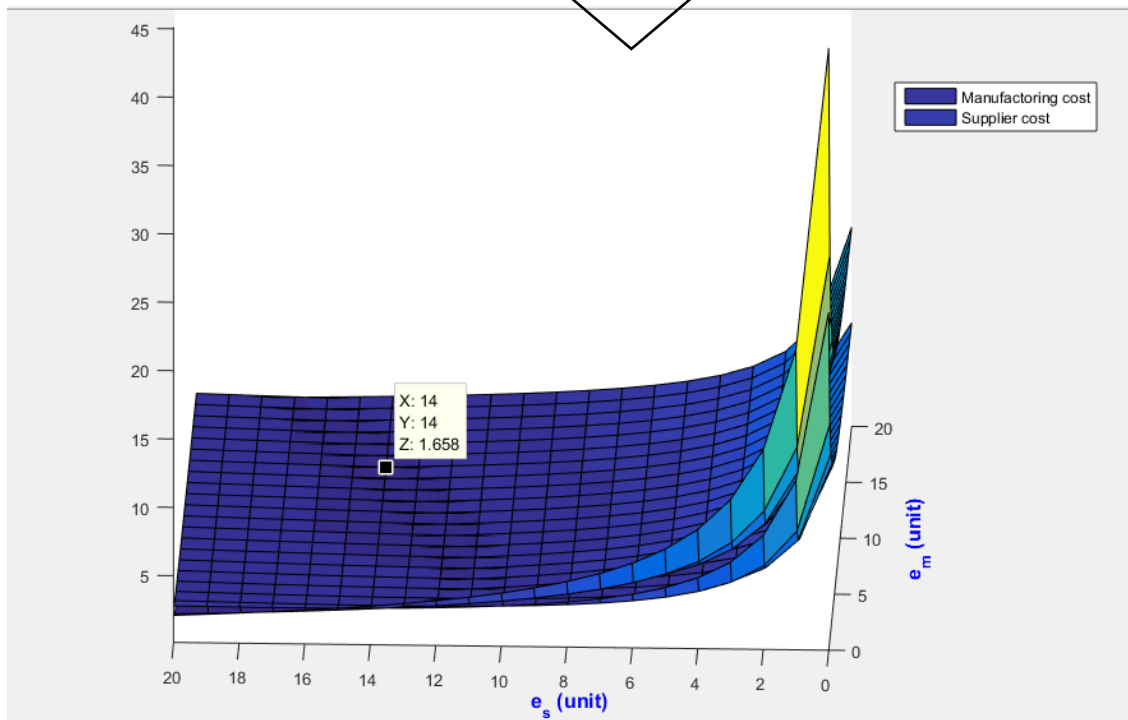


Figure 5 Optimal k for lowest control cost at both levels



iPhone 5 case

Parameter	Value	Unit
r_s	0.05	% units of a batch
r_m	0.01	% units of a batch
c_s	2.5	\$ per unit
c_m	15	\$ per unit
d_s	5	\$ per unit destructed at supplier's level
d_m	50	\$ per unit destructed at manufacturer's level
P	100000	\$ per contaminated unit that reached to customer

Estimations are based on the basis of iPhone 5 market price. In this paper we suppose that iPhone 5 battery production cost per unit is 25 US dollars and a finished product by manufacturer, or what is called the product cost is 150 US dollars. This makes 125 US dollars production cost per unit left for the manufacturer.

If $k=0$

As in the previous case, we suppose a batch of a hundred units to simplify the understanding of the numerical results. As the reader can see, the size of the batch does not incur in the results, it is set to 100 units only to facilitate the results.

So, if the batch is 100 units, and manufacturer cost of producing a unit of iPhone 5 is around 125 US dollars and supposing a maximum investment of 15% of total cost in quality control, which is a really high percentage, the maximum total control cost admissible would be under 1875 US dollars. Checking on the graphs below, resulting from simulating the model, we can see and we expected that no quality control would cost more money for the manufacturer. Since supplier has no responsibility on public threat cost, it is obvious to expect that this part will do no control, therefore manufacturer will suppose e_s equals to zero. Assuming that our model is right, manufacturer would decide to do quality control only under the permission of having a profit on its product. And the best option is to do 100% inspection of the units since P is too high to be assumed by the manufacturer, if a contaminated unit reaches to a customer.

The main difference between this case and the previous one is that even if $k=0$, meaning that supplier has no responsibility in the Public Health Cost which is represented by P , the manufacturer's total control cost is still affordable, although high. This is due to the cause that the profit margin for the manufacturer is way higher than the supplier. And maybe, another reason would be that risk is quite lower at manufacturer level than supplier's since Apple Inc is a high-tech company and there is a very high standard of quality implemented already.

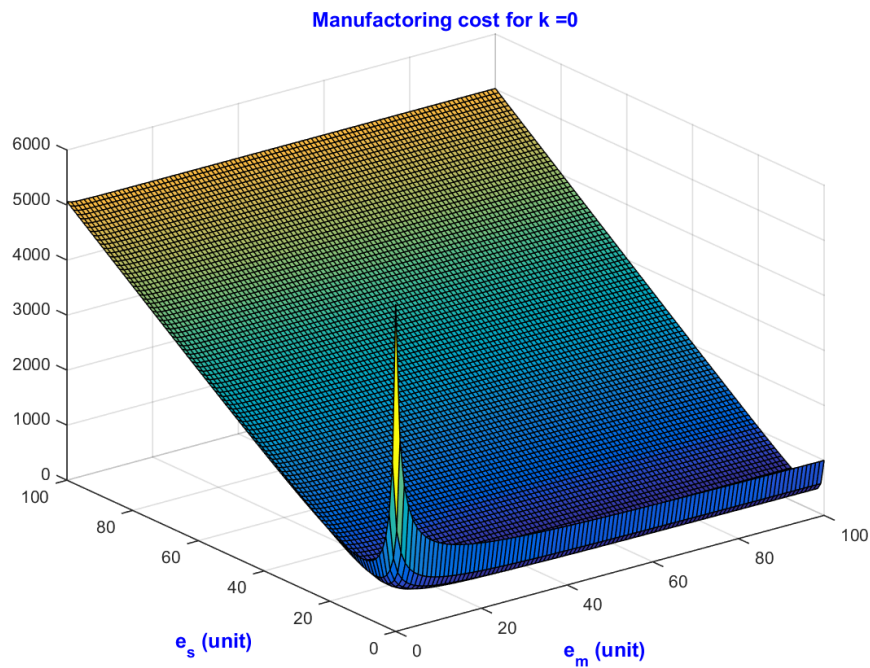


figure 6 manufacturer's total control cost at $k=0$

At supplier's level, for a $k=0$, no quality control at all would be the best choice for this part. It should skip all quality control process to cut down cost since no responsibility is required from his part. Below, in the figure 2 is shown the total control cost assumed by supplier, as it can be expected is much lower compared to manufacturers. Even it can reach to no cost, however this might not be realistic, if a supplier provides bad quality products is not probable to be chosen as supplier for a company such as Apple Inc. So this case is unrealistic.

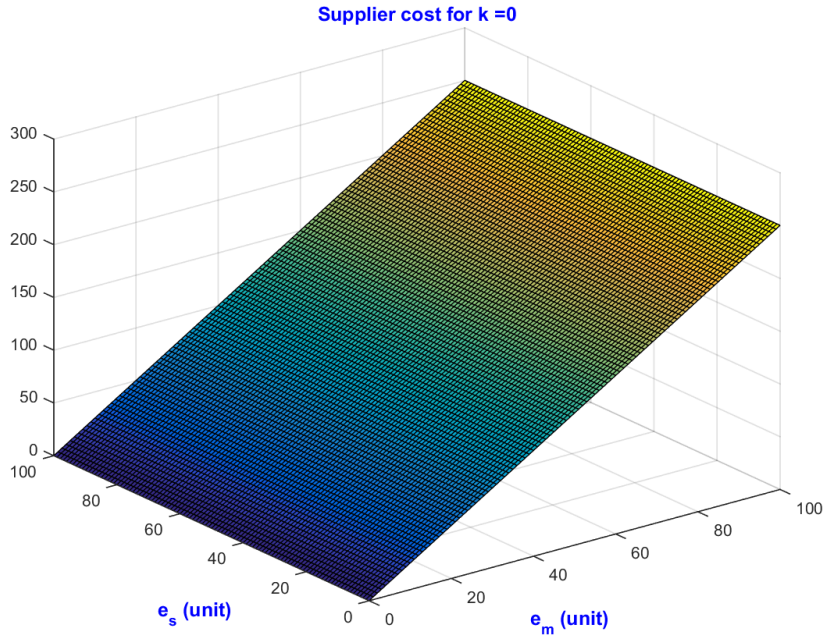


figure 7 Supplier's total control cost at $k=0$

For $k=0.5$

If Health Threat Cost P is equally shared by both implied parts, manufacturer and supplier's difference at cost at control is dismantled. Assuming the best response from the supplier, which means an $e_s=7.32\%$, the manufacturer's minimum control cost can be reached by doing an $e_m=8.71\%$. The result of this combination, which is the result expected by the manufacturer has a total control cost of 345,87 US dollars per batch. Compared to the maximum admissible, which is 1875 US dollars per batch, this total control cost is totally affordable by the manufacturer.

Similarly, for an equal share of responsibility, supplier's control cost depends on the manufacturer's effort. In the supplier's total control cost model, if manufacturer's best response is expected, which in this case is $e_m=4.76\%$, the relative lowest total control cost for supplier is 563.76 US dollars per batch with an effort of $e_s=7.85\%$. This might be a too high cost to the supplier to bear and so, optimal k should be set in between 0 and 0.5.

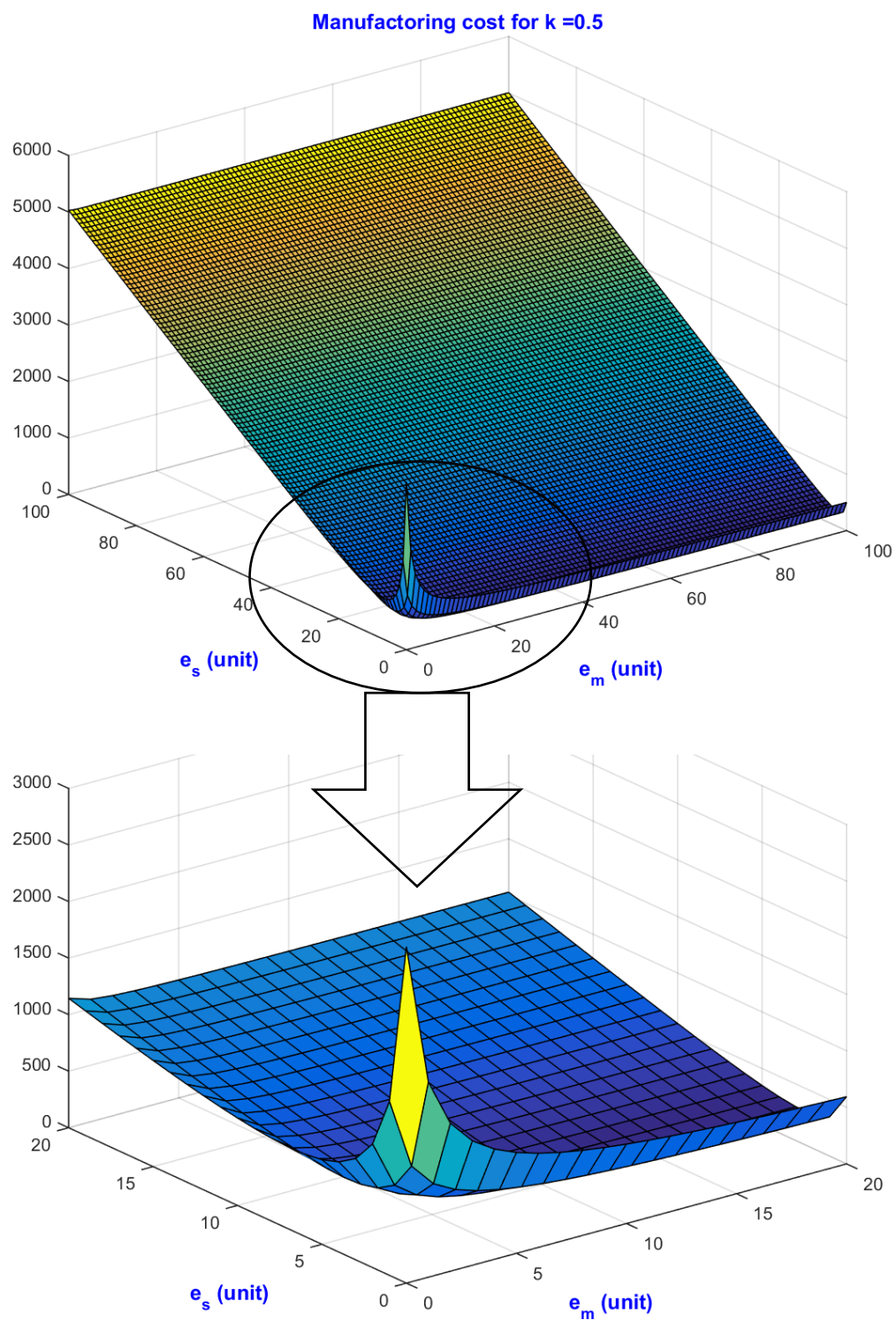


figure 7 Manufacturer's total control cost at $k=0.5$

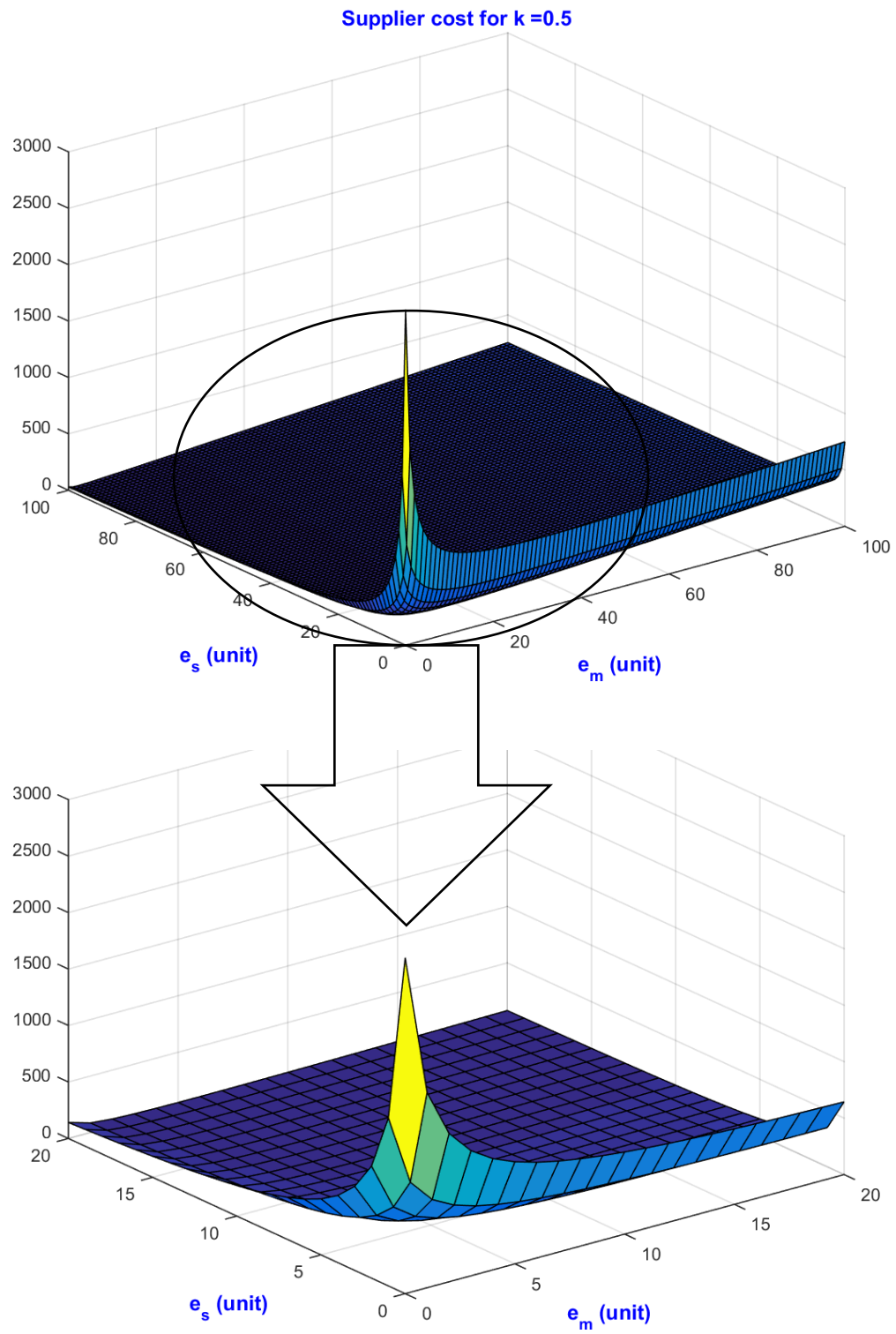


figure 8 Supplier's total control cost at $k=0.5$

Optimal k for minimal total control cost in both levels

In order to find the optimal total cost for both supplier and manufacturer, being the perfect couple of effort applied by each level e_s^*, e_m^* , we have simulated through the model with Matlab with a k_step equal to 0.1 (see simulations in Annex 4). We found out that the perfect couple can be found at the agreement level of $k=0.34$. In this case of Winery, optimal effort in control at supplier level would be $e_s^* = 2.75\%$ and $e_m^* = 7.85\%$, which means a total control cost of 254.75US dollars per batch for the supplier and a total cost of 431.83US dollars per batch for the manufacturer.

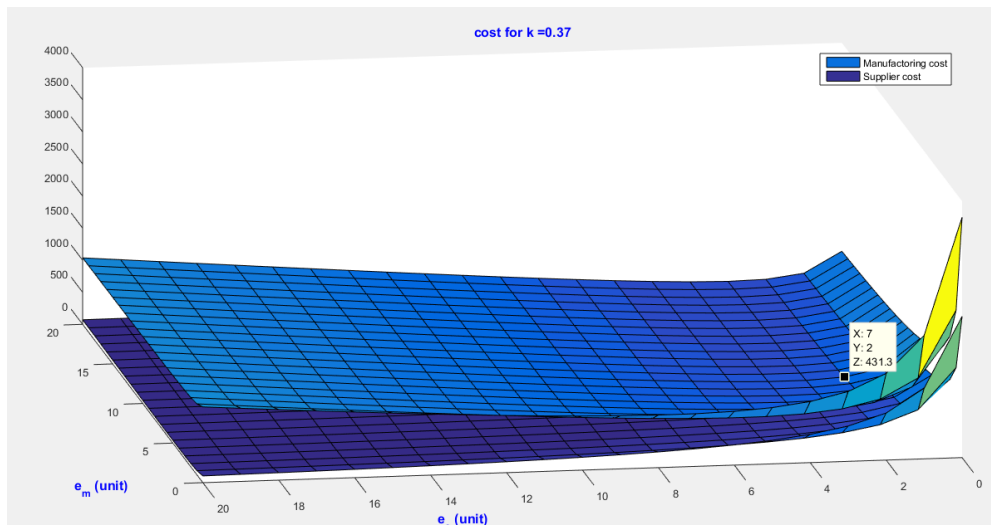


figure 8 Optimal k for lowest control cost at both levels

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Annex 1 Arsenic contaminated wine news

Should you be worried about arsenic in California wine?

By Emanuella Grinberg, CNN

Updated 2047 GMT (0347 HKT) March 29, 2015

(CNN)A lawsuit that's stirring concern among drinkers of some California wine starts with a history lesson.

The deaths of Napoleon Bonaparte, Simon Bolivar, King George III, King Faisal I and other prominent figures have been attributed to arsenic poisoning, the first paragraph of the 30-page complaint says.

And, now, drinkers of some California wine have become "unwitting 'guinea pigs' of arsenic exposure," thanks to the negligent and misleading actions of dozens of California wineries, according to the class action complaint filed March 19 on behalf of two California couples.

The lawsuit does not include any allegations of physical injury or death due to arsenic consumption associated with drinking the wines named in the complaint. The plaintiffs are seeking monetary damages and a court order requiring the defendants disclose on the bottles the risks of consuming inorganic arsenic in wines and engage in "corrective advertising" regarding their conduct.

News of the lawsuit, which broke last week, struck fear in the hearts of frugal wine consumers nationwide, prompting many to share lists on social media of labels named in the lawsuit, all but declaring the outcome a foregone conclusion.

The complaint names 28 companies that represent 83 low-cost labels familiar to supermarket wine aisle shoppers: Cupcake, Franzia, Flipflop, Rex Goliath and Korbel, among others. Even the maker of Trader Joe's Charles Shaw Zinfandel varietal (affectionately known among fans as "two-buck Chuck"), was called out for allegedly failing to warn consumers that it contained "dangerously" high levels of inorganic arsenic.

But should consumers start looking to other winemakers or other wine-producing states for gallon-sized bottles of zinfandel? Or is the lawsuit a fearmongering tactic being used to drum up business for the beverage-testing company used for the lawsuit, as some defendants and industry insiders have insinuated?

Most of the defendants said their wine was safe to drink when contacted by CNN. Some declined to comment, citing the pending litigation. Others referred CNN to the Wine Institute, a California trade group that called the claims "false and misleading."

"We are concerned that the irresponsible publicity campaign by the litigating party could scare the public into thinking that wine is not safe to consume, which is patently untrue," said the group, which represents 1,000 California wineries, including 10 of the defendants.

The lawsuit alleges that three separate labs "skilled in arsenic testing" independently confirmed that the defendants produce wines containing "dangerously" high levels of inorganic arsenic, in some cases up to 500% more than what is considered acceptable.

"Put differently," the complaint states in bold letters, "just a glass or two of these arsenic-contaminated wines a day over time could result in dangerous arsenic toxicity to the consumer."

A spokesman from the public relations firm representing the plaintiffs and BeverageGrades, which performed the analysis, said the company is confident that its data is "based on sound scientific research." Because the company expects testing methodology to be at issue in litigation, it declined to reveal specific data or testing methods.

"We understand the public interest in this story and look forward to resolving the litigation to make these products safer for consumers. And we hope the winemakers will take these findings just as seriously and work to make sure their wines are safe," spokesman Rob Feldman said.

Without seeing the lab results, experts suggest reserving judgment based on the following issues to arise from the lawsuit:

Trace amounts of arsenic naturally exist in food and water

Arsenic is found in air, soil and water throughout the world. Therefore, it can also be found in grains, fruits, vegetables and seafood due to absorption through soil and water.

"Plants take up trace amounts of arsenic from the soil, and we have been ingesting these trace amounts for all of human history. Generally, these amounts are at levels well below that associated with either acute or chronic toxicity," said Cornell University's Gavin Lavi Sacks, director of undergraduate studies for the viticulture and enology program in the College of Agricultural and Life Sciences.

Arsenic occurs in inorganic and organic forms. The FDA describes organic or naturally occurring arsenic as "essentially harmless." Inorganic arsenic has been classified as a human carcinogen by the Environmental Protection Agency.

The first time the U.S. Food and Drug Administration set limits for arsenic levels in food or drink was in 2013, when it proposed to limit the amount of inorganic arsenic in apple juice to 10 parts per billion.

Long-term exposure to inorganic arsenic, mainly through smoking, drinking contaminated water, eating food prepared with contaminated water or eating food irrigated with arsenic-rich water, can lead to health risks such as cancer and skin lesions.

According to the lawsuit, inorganic arsenic makes up the "overwhelming majority" of arsenic in wines at issue, despite the winemakers' ability to limit inorganic arsenic through "responsible winemaking procedures" and "sophisticated testing equipment."

Without providing specific data, the plaintiffs said their analysis found inorganic arsenic "far in excess" of what's allowed in drinking water based on the EPA's standard for arsenic in drinking water: 10 parts per billion.

But the EPA limit for water is based on total arsenic, including both organic and inorganic forms, leading some to question whether it's the best basis for comparison.

The lawsuit uses the EPA standard for arsenic in drinking water as a reference point

This standard is set to protect consumers served by public water systems from the effects of long-term, chronic exposure to arsenic, EPA spokeswoman Tara Johnson said in an email. It's based on how much water people typically drink daily, which ranges from one to two liters, she said.

However, the EPA standard for arsenic in drinking water "is of limited use when considering any potential health risks related to arsenic in wine," FDA spokeswoman Lauren Sucher said in an email to CNN.

"People drink far more water than they do wine over their lifetimes, and they start drinking water earlier in life. Thus, both the amount and period of exposure are different and would require separate analyses," she said.

Seeing as the USDA recommends drinking about 10 cups of water a day and no more than two alcoholic drinks (about 1 cup of wine) a day, "a sensible concentration limit for arsenic in wine should be at least 10-fold higher than for drinking water, and possibly higher, since we also use water for cooking and cleaning," Sacks of Cornell University said.

This is roughly the case in countries that have established limits for arsenic in wine, which leads to the next point:

California wine is good enough for countries with established standards for arsenic in wine

The U.S. Tax and Trade Bureau regulates the production of alcoholic beverages, and part of this process is testing wine for arsenic, said Erika Holmes, spokeswoman for Washington State University's Viticulture and Enology school.

Even though the FDA has not established a standard for acceptable levels of arsenic in wine, California wine exports are tested and found to be below the established limits for export, Holmes said in an email.

Countries that import California wine also test for arsenic using their own standards: 100 parts per billion in Canada and 200 parts per billion in Europe -- 10 to 20 times higher than the drinking water limit in the United States.

"It's certainly appropriate to look to other countries' regulations for guidance," Sacks said. "Their regulators are presumably looking at the same body of research that U.S. regulators would look to if they were to establish a mandatory limit for wine."

The company that performed the analysis also sells alcohol analysis services

The day CBS News aired a segment on the lawsuit, the company that performed the analysis sent out a news release offering its services to provide "reassurance from arsenic in wine" through "a tool for screening their offerings to ensure the quality of their supply chain."

Neither BeverageGrades nor its CEO, Kevin Hicks, is a party to the lawsuit. But Hicks' appearance in the segment prompted detractors to cry conflict of interest.

In a statement to CNN, Hicks said it was concerning that some winemakers would point to this as a conflict of interest "instead of focusing on making sure their product contains the lowest amount of contaminants possible."

He also defended his company's right to offer its services to retailers, saying he will continue to do so.

"The arsenic data in my testing is based on years of scientific research and operating a commercial chemistry lab for over two years. As a commercial lab no one should be surprised that BeverageGrades has been offering lab testing services to the alcohol beverage industry since July 2013."

A previous version of this story incorrectly stated that the brand Barefoot was a named defendant in the lawsuit. It is not. This story has been corrected. CNN sincerely regrets the error.

Is Your Favorite Wine Tainted with Arsenic?

Does your wine make the list?

You've likely browsed through the wine selection at Trader Joe's (among other stores) and thought – wow, I could drink wine that's cheaper than bottled water! Many Trader Joe's customers have flocked to the store for years to get their hands on some cheap vino, but there are some nasty, carcinogenic toxins in that wine which may cause you to think again before picking up a bottle for your next dinner party.

How About Some Inorganic Arsenic with That Cheese?

It turns out that among hundreds of wineries (many of which supply stores like Trader Joe's), vintages both old and young contain dangerous levels of arsenic.

Wine industry spokespersons among the 28 wineries that are defendants in a current lawsuit point out that the wine industry in Europe, Canada, and the USA has its own arsenic level standards for wine, amounting to 100 parts per billion. Despite this, approximately half of the wine recently tested had higher arsenic levels than even the EPA's standards allow.

Though the class action suit has yet to appear before a judge or jury, consumers can make their own informed decisions now, about what kind of wine they are willing to drink.

The lawsuit stems from Kevin Hicks, a former wine distributor who started BeverageGrades, a Denver-based lab that tested 1,300 bottles of California wine. The lab found that about a quarter of them had higher levels of arsenic than the maximum limit allowed in water.

The most alarming fact – the cheaper the wine, the higher the levels of arsenic. So, that trip to Trader Joe's means you are drinking poison for pennies.

Specific labels of Trader Joe's named Charles Shaw or "Two-Buck Chuck," Sutter Home, Franzia, Beringer, and Cupcake were among the cheap wines with the highest levels of arsenic.

The lawsuit alleges that the contaminated wines are cheaper in part because their producers don't "implement the proper methods and processes to reduce inorganic arsenic."

Whether this is done at the winery, by the bottler, or by the wine grower – it doesn't matter. No one should be drinking wine that has such high levels of toxicity.

The lawsuit seeks measures to attain arsenic levels which are closer to the EPA's 10 parts per billion (arsenic to water) standard, and not boast of 50 parts to billion, which is highly alarming.

The following wines are the subjects of the class action lawsuit. You can also check this site to see the wines which turned up the lowest amounts of heavy metals.

Acronym GR8RW Red Blend 2011

Almaden Heritage White Zinfandel

Almaden Heritage Moscato

Almaden Heritage White Zinfandel

Almaden Heritage Chardonnay

Almaden Mountain Burgundy

Almaden Mountain Rhine

Almaden Mountain Chablis

Arrow Creek Coastal Series Cabernet Sauvignon 2011

Bandit Pinot Grigio

Bandit Chardonnay

Bandit Cabernet Sauvignon

Bay Bridge Chardonnay

Beringer White Merlot 2011

Beringer White Zinfandel 2011

Beringer Red Moscato

Beringer Refreshingly Sweet Moscato

Charles Shaw White Zinfandel 2012

Colores del Sol Malbec 2010

Glen Ellen by Concannon's Glen Ellen Reserve Pinot Grigio 2012

Concannon Selected Vineyards Pinot Noir 2011

Glen Ellen by Concannon's Glen Ellen Reserve Merlot 2010

Cook Spumante

Corbett Canyon Pinot Grigio

Corbett Canyon Cabernet Sauvignon

Cupcake Malbec 2011

Fetzer Moscato 2010
Fetzer Pinot Grigio 2011
Fisheye Pinot Grigio 2012
Flipflop Pinot Grigio 2012
Flipflop Moscato
Flipflop Cabernet Sauvignon
Foxhorn White Zinfandel
Franzia Vintner Select White Grenache
Franzia Vintner Select White Zinfandel
Franzia Vintner Select White Merlot
Franzia Vintner Select Burgundy
Hawkstone Cabernet Sauvignon 2011
HRM Rex Goliath's Moscato
Korbel Sweet Rose Sparkling Wine
Korbel Extra Dry Sparkling Wine
Menage a Trois Pinot Grigio 2011
Menage a Trois Moscato 2010
Menage a Trois White Blend 2011
Menage a Trois Chardonnay 2011
Menage a Trois Rose 2011
Menage a Trois Cabernet Sauvignon 2010
Menage a Trois California Red Wine 2011
Mogen David Concord
Mogen David Blackberry Wine
Oak Leaf White Zinfandel
Pomelo Sauvignon Blanc 2011
R Collection by Raymond's Chardonnay 2012
Richards Wild Irish Rose Red Wine
Seaglass Sauvignon Blanc 2012
Simply Naked Moscato 2011
Smoking Loon Viognier 2011

Sutter Home Sauvignon Blanc 2010
Sutter Home Gewurztraminer 2011
Sutter Home Pink Moscato
Sutter Home Pinot Grigio 2011
Sutter Home Moscato
Sutter Home Chenin Blanc 2011
Sutter Home Sweet Red 2010
Sutter Home Riesling 2011
Sutter Home White Merlot 2011
Sutter Home Merlot 2011
Sutter Home White Zinfandel 2011
Sutter Home White Zinfandel 2012
Sutter Home Zinfandel 2010
Trapiche Malbec 2012
Tribuno Sweet Vermouth
Vendange Merlot
Vendange White Zinfandel
Wine Cube Moscato
Wine Cube Pink Moscato 2011
Wine Cube Pinot Grigio 2011
Wine Cube Pinot Grigio
Wine Cube Chardonnay 2011
Wine Cube Chardonnay
Wine Cube Red Sangria
Wine Cube Sauvignon Blanc 2011
Wine Cube Cabernet Sauvignon/Shiraz 2011

Annex 2 iPhone 5 battery recall

Apple has determined that a very small percentage of iPhone 5 devices may suddenly experience shorter battery life or need to be charged more frequently. The affected iPhone 5 devices were sold between September 2012 and January 2013 and fall within a limited serial number range. If your iPhone 5 is experiencing these symptoms and meets the eligibility requirements noted below, Apple will replace your iPhone 5 battery, free of charge.

Eligibility

If your iPhone is in working order and exhibits the symptoms noted above, use the serial number checker below to see if it is eligible for this program.

Replacement process

Choose one of the service options below to have your battery replaced. Your iPhone will be examined prior to any service to verify that it is eligible for this program and in working order.

Please call your service provider to confirm that battery replacement service is available on the day you visit them.

- Apple Authorized Service Provider
- Apple Retail Store
- Apple Technical Support

To prepare your iPhone 5 for the battery replacement process, please follow the steps below:

- Back up your data to iTunes or iCloud
- Turn off Find my iPhone
- Erase data and settings in Settings > General > Reset > Erase all Content and Settings

Note: If your iPhone 5 has any damage such as a cracked screen which impairs the replacement of the battery, that issue will need to be resolved prior to the battery replacement. In some cases, there may be a cost associated with the repair.

Additional Information

Apple may restrict or limit repair to the original country of purchase. If you believe your iPhone 5 was affected by this issue, and you paid to replace your battery, you can contact Apple about a refund. This worldwide Apple program doesn't extend the standard warranty coverage of the iPhone 5.

The program covers affected iPhone 5 batteries for 3 years after the first retail sale of the unit.

Information as of 2015-03-05

Annex 3 Matlab program for simulations

% Plot the cost funtion

% Parameters:

 % rs: % units of a batch

 % rm: % units of a batch

 % ds: \$ per unit destructed at supplier's level

 % dm: \$ per unit destructed at manufacturer's level

 % cs: \$ per unit

 % cm: \$ per unit

 % P: \$ per contaminated unit that reached to customer

% Execution example:

 % grafica2(0.05,0.03,0.2,0.5,0.045,0.15,20)

function grafica2 (rs,rm,ds,dm,cs,cm,P)

 close all;

 % Defined values

 limit_es = 100;

 limit_em = 100;

 step_es = 1;

 step_em = 1;

 step_k = 0.1;

 %Number argument check

 if nargin ~=7

 error ('num argument error');

 end

 % create the graphic folder

 warning('off','MATLAB:MKDIR:DirectoryExists');

 err = mkdir ('graphics');

 if err ~= 1

```

        error ('error creating the folder graphics for the results');
    end

    % init step of vector K values
    vec_k= 0:step_k:1;

    % init the grid [X,Y] (values for es and em) for the cost function
    [es,em]= meshgrid(0:step_es:limit_es,0:step_em:limit_em);

    %iteration for each k
    for k= vec_k

        %IMPORTANT NOTE: the .* and ./ operator is aplied to operate each element
        of a matrix/vector

        % calculating the prob. of contamination detection -> supplier
        ps_fun = es./(es+1);

        % calculating the prob. of contamination detection -> manufactor
        pm_fun = em./(em+1);

        % calculating probability of a public health threat
        p_fun = rs*(1-ps_fun).*(1-pm_fun)+(1-rs)*rm*(1-pm_fun);

        % calculating manufacturing cost
        Cost_m = cm*em+p_fun*(1-k)*P+(rs*(1-ps_fun).*pm_fun+(1-
rs)*rm*pm_fun)*dm;

        % calculating supplier cost
        Cost_s = cs*es+p_fun*k*P+rs*ps_fun*ds;

        % set the name of the windows and title of the plot (manufactor)
        name = strcat ('Manufactoring cost for k = ', num2str(k));

        % set windows name
        figure('name',name,'NumberTitle','off');

        % plot 3d graphic
        graph = surf(es,em,Cost_m);

        % set labels, and title
        title(name,'FontSize',12,'FontWeight','bold','Color','blue');
    end

```



```

        xlabel('e_{m} (unit)','FontSize',12,'FontWeight','bold','Color','blue');
ylabel('e_{s} (unit)','FontSize',12,'FontWeight','bold','Color','blue');

        % save the result graphic to the graphic folder
saveas(graph, strcat('graphics/', name, '.png'));

% set the name of the windows and title of the plot (supplier)
name = strcat ('Supplier cost for k = ', num2str(k));
% set windows name
figure('name', name, 'NumberTitle', 'off');
% set labels, and title
graph = surf(es, em, Cost_s);
title(name, 'FontSize', 12, 'FontWeight', 'bold', 'Color', 'blue');
xlabel('e_{m} (unit)', 'FontSize', 12, 'FontWeight', 'bold', 'Color', 'blue');
ylabel('e_{s} (unit)', 'FontSize', 12, 'FontWeight', 'bold', 'Color', 'blue');

        % save the result graphic to the graphic folder
saveas(graph, strcat('graphics/', name, '.png'));

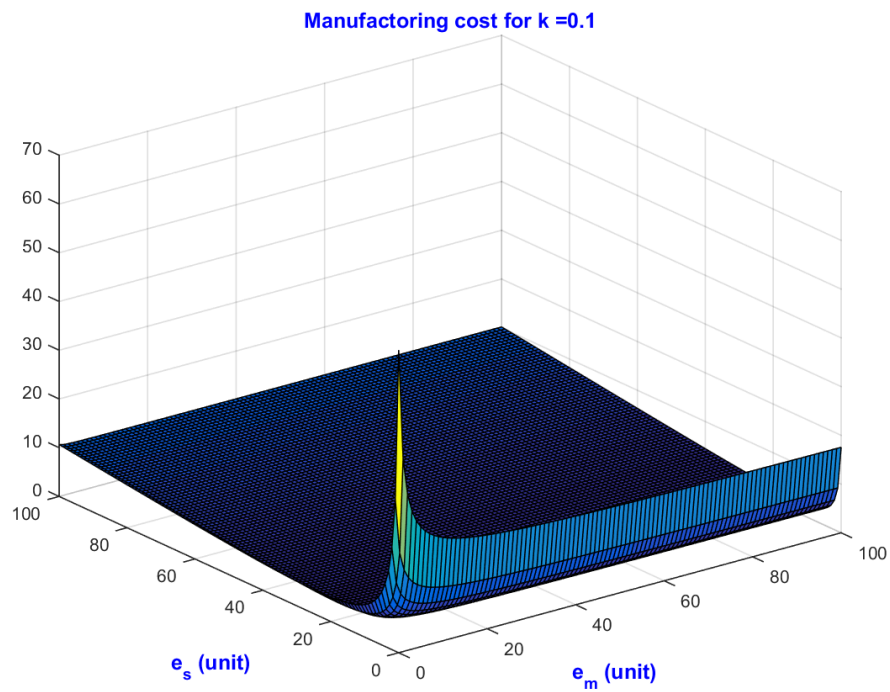
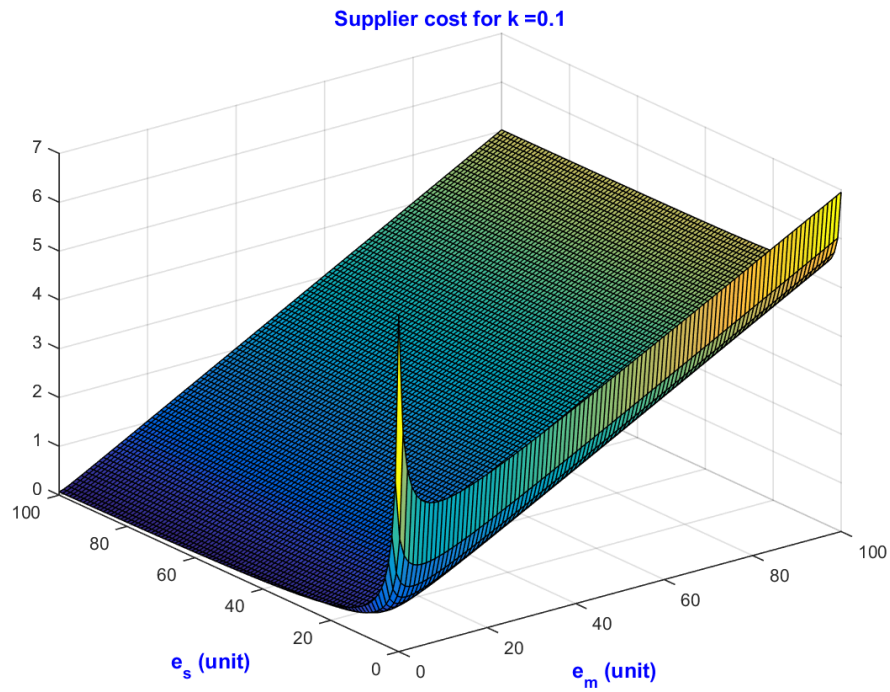
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end

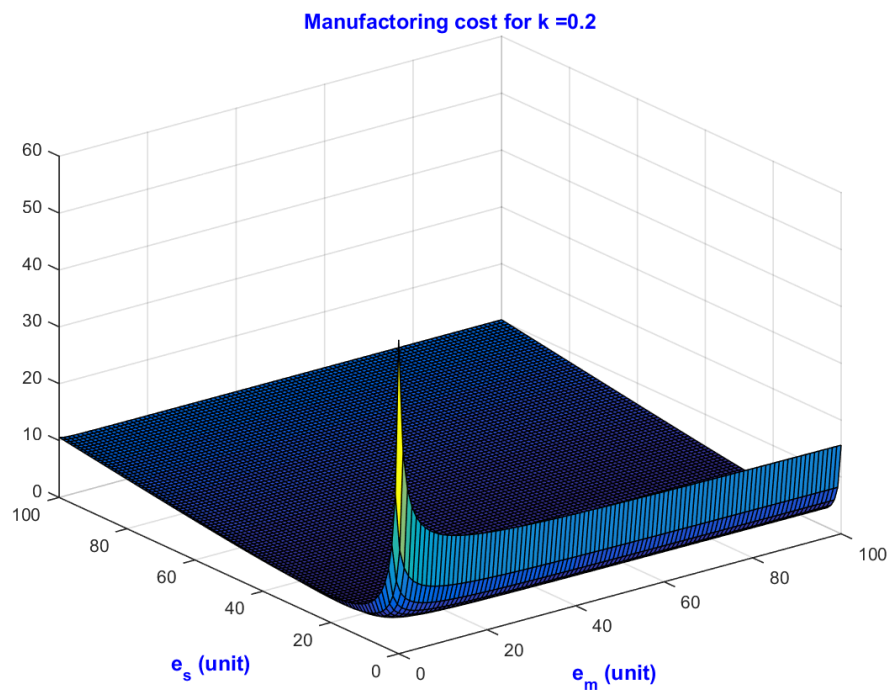
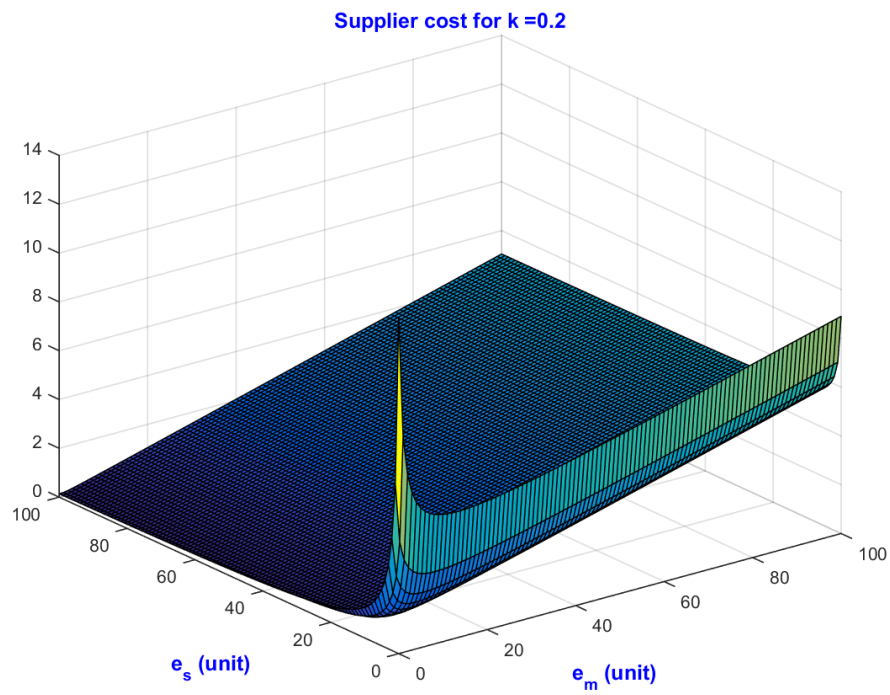
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Annex 4 Simulation graphics for winery case

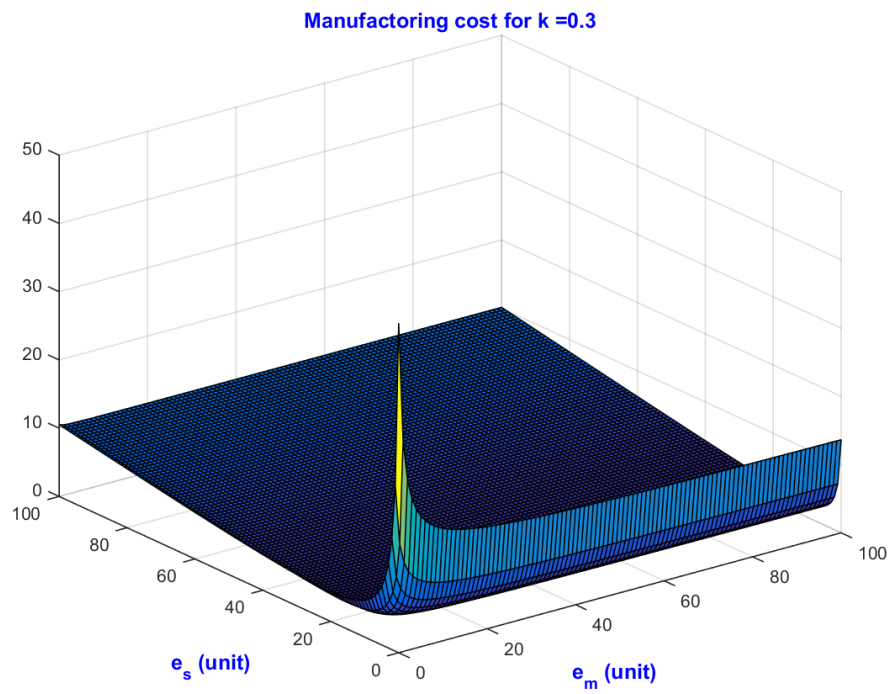
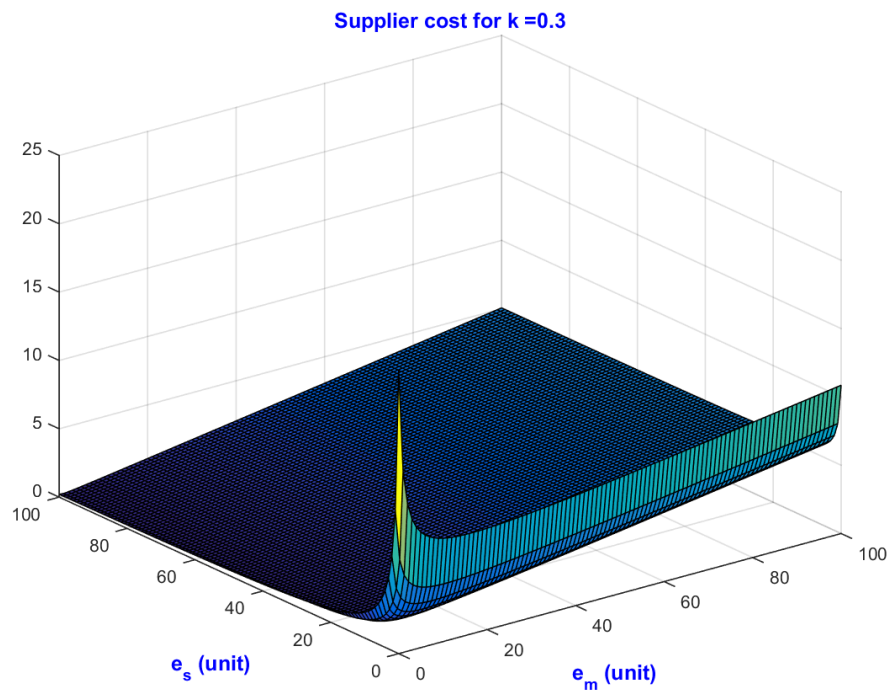
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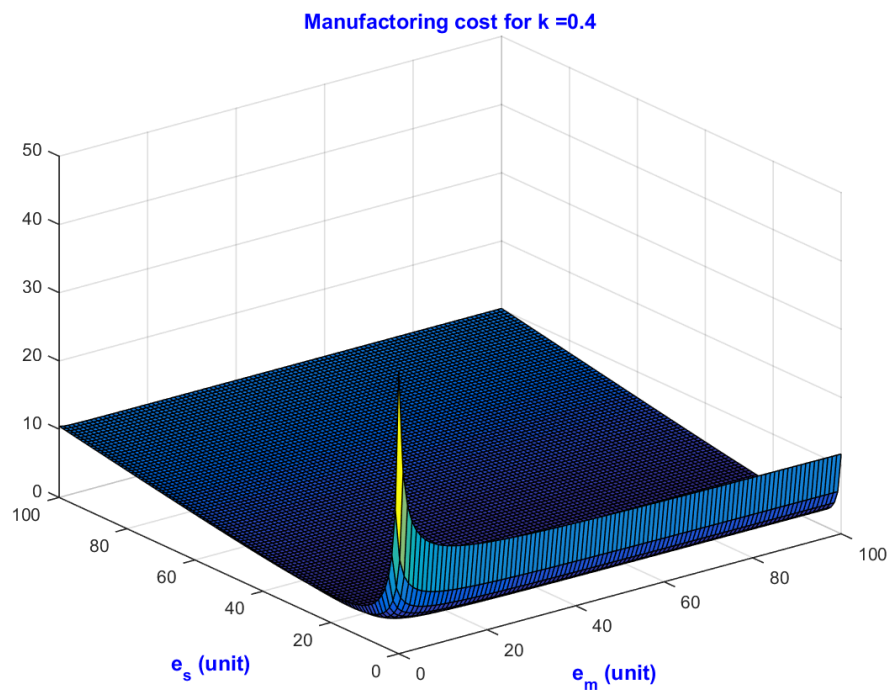
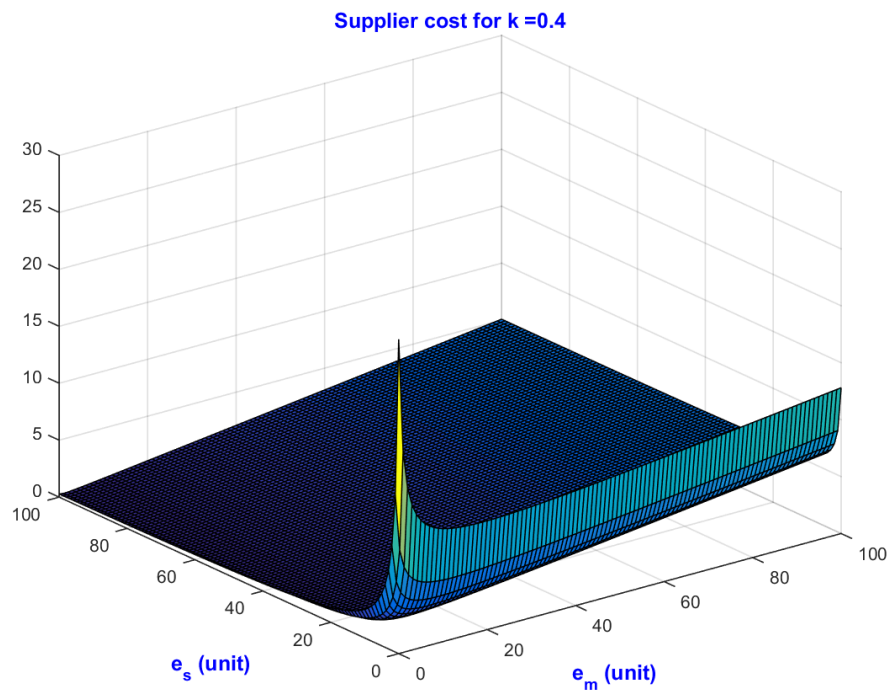
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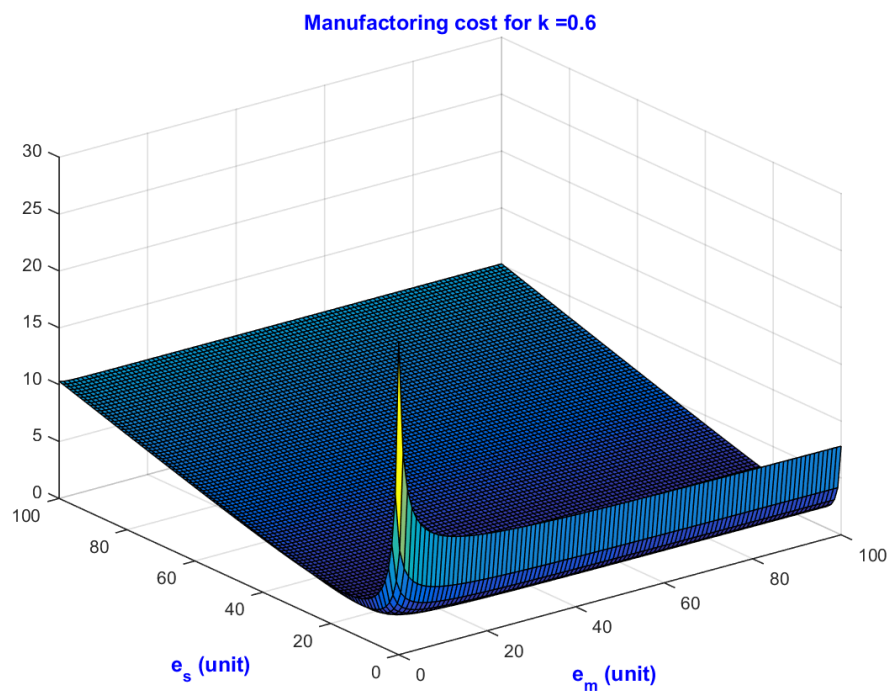
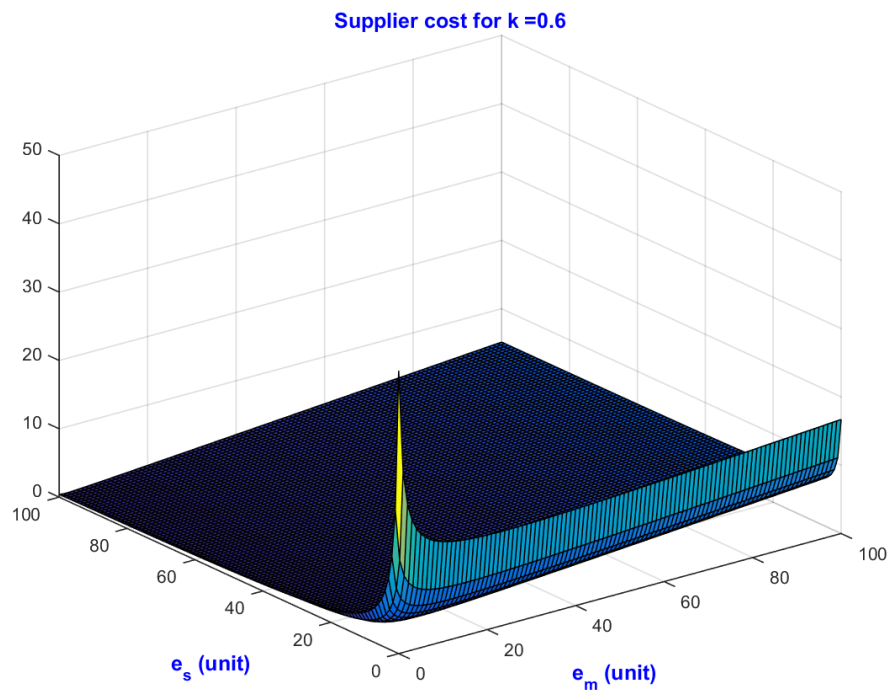
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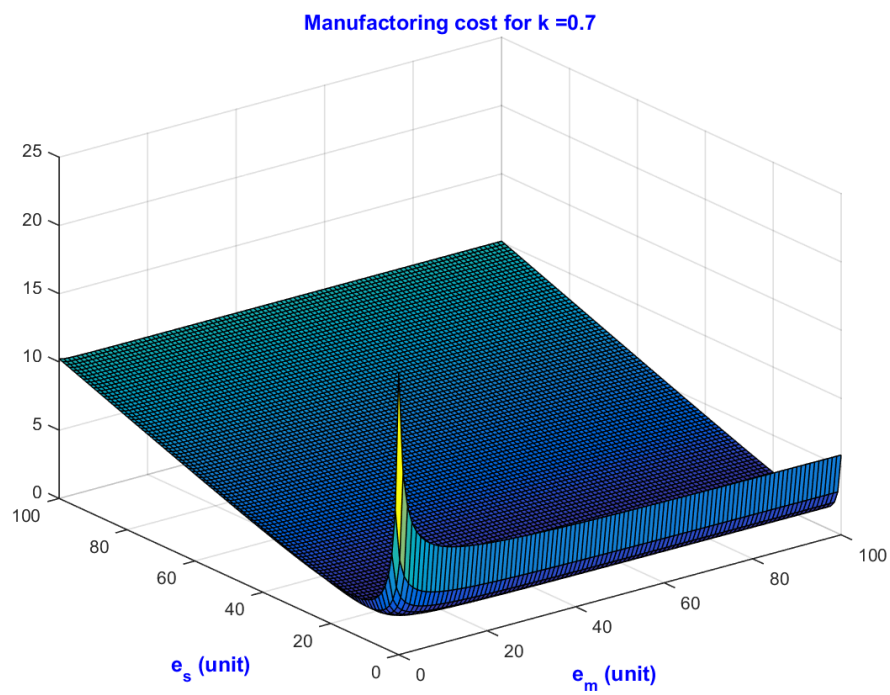
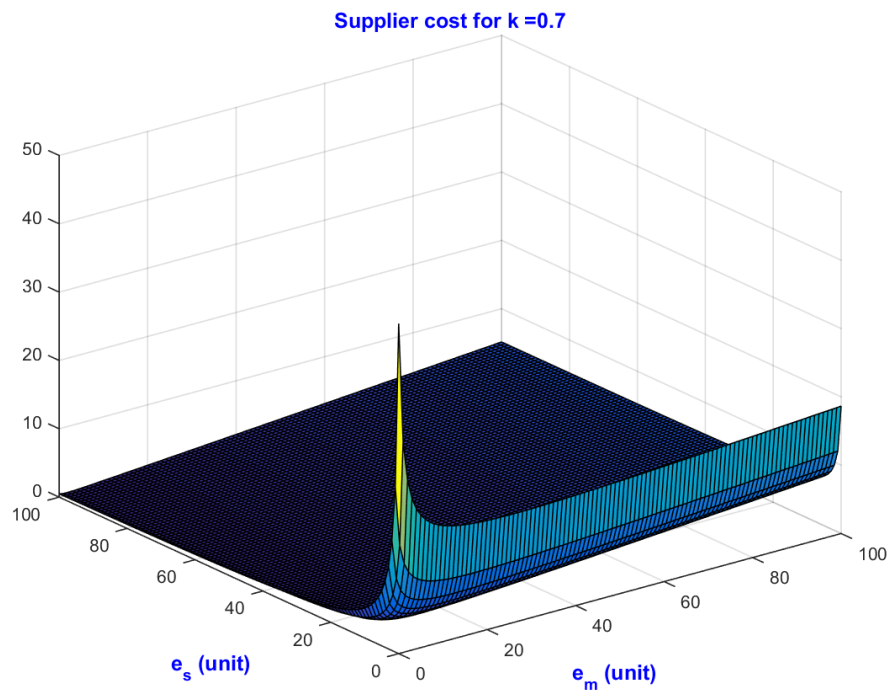
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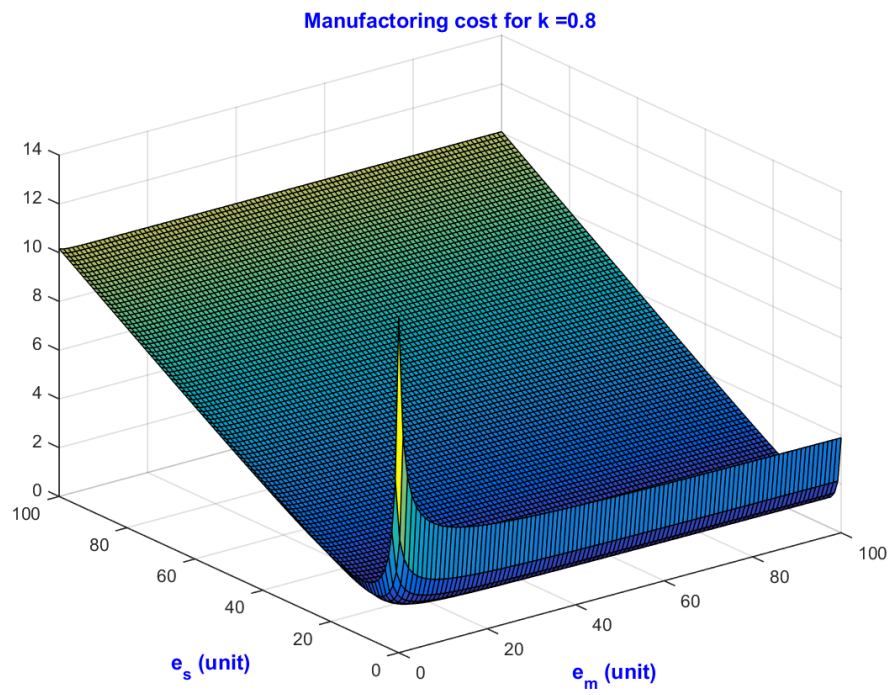
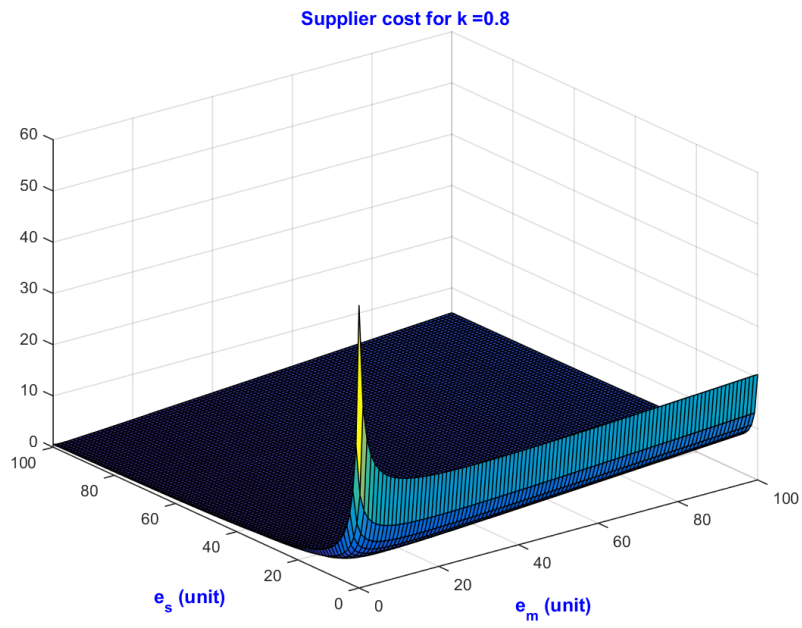
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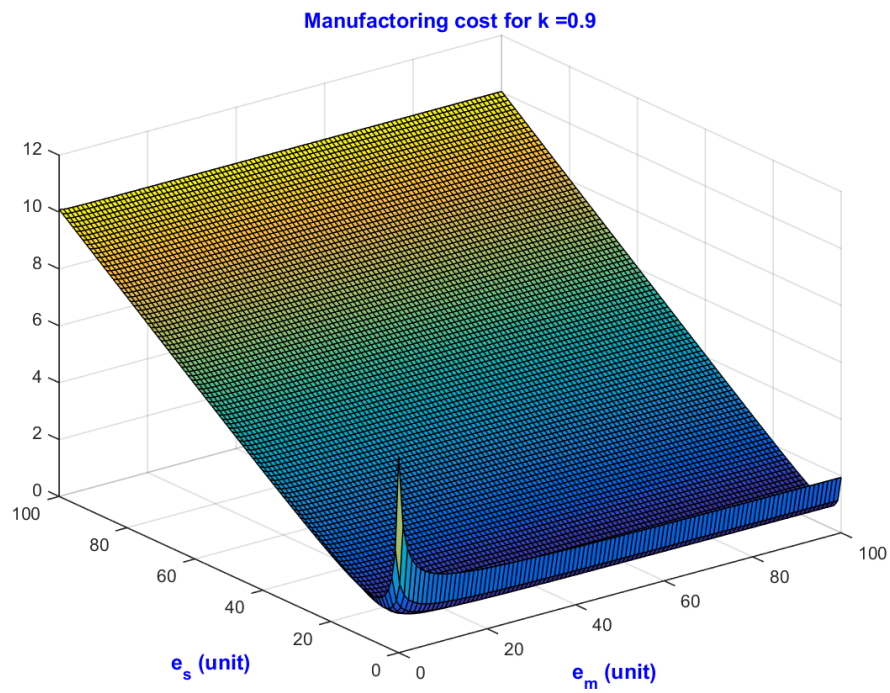
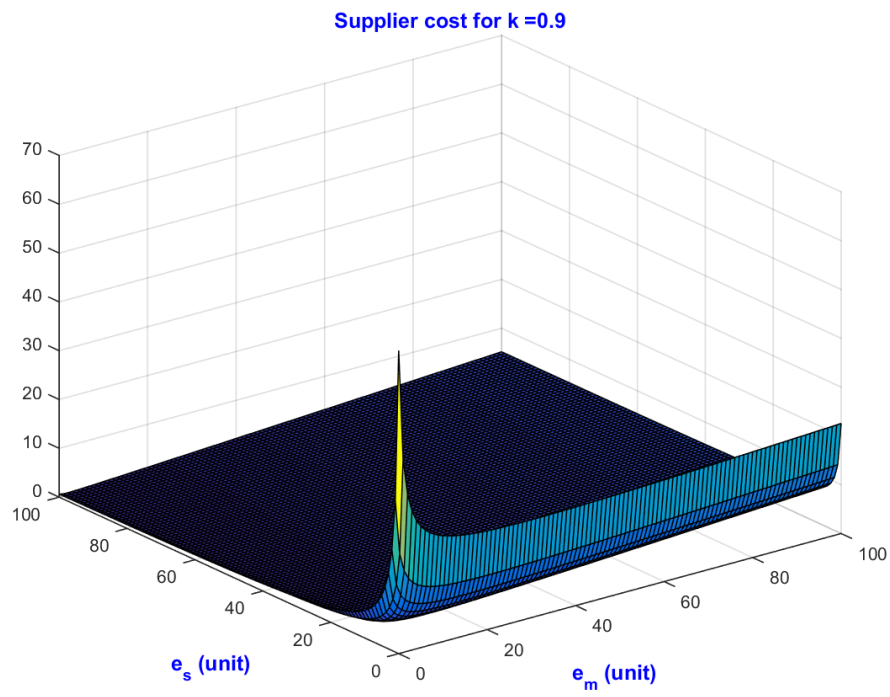
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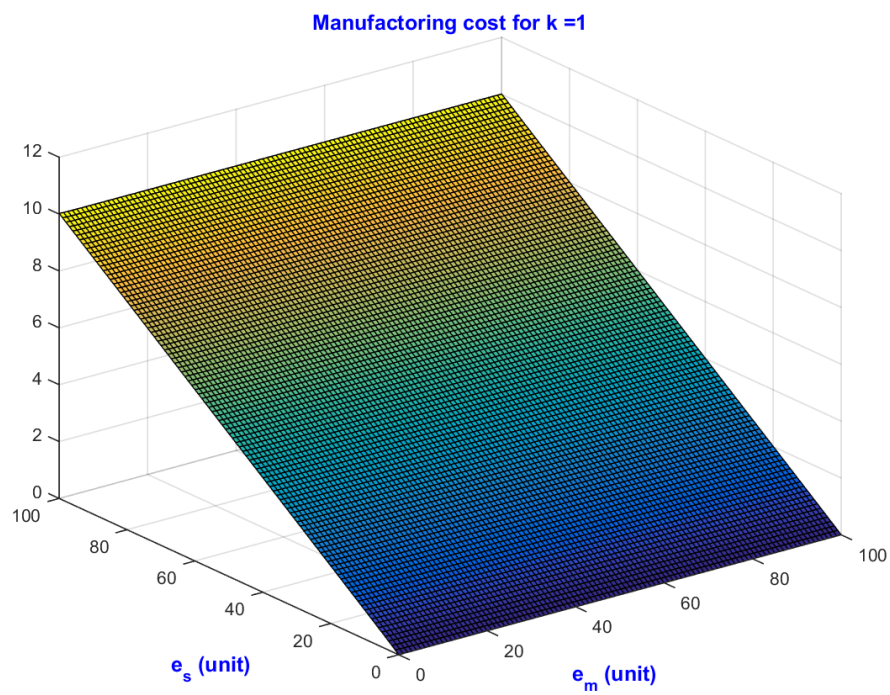
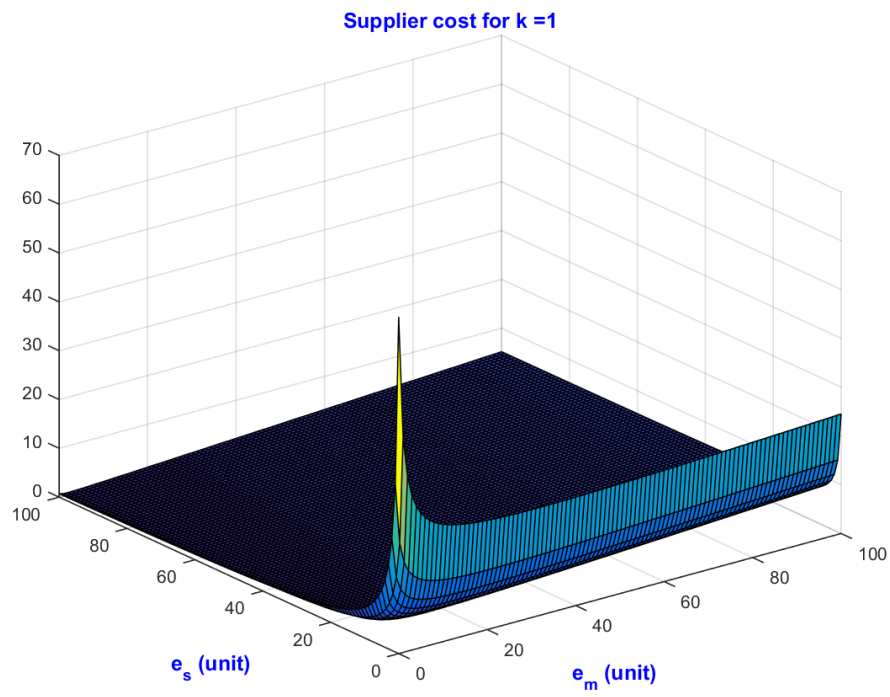
$K=0.8$



$K=0.9$

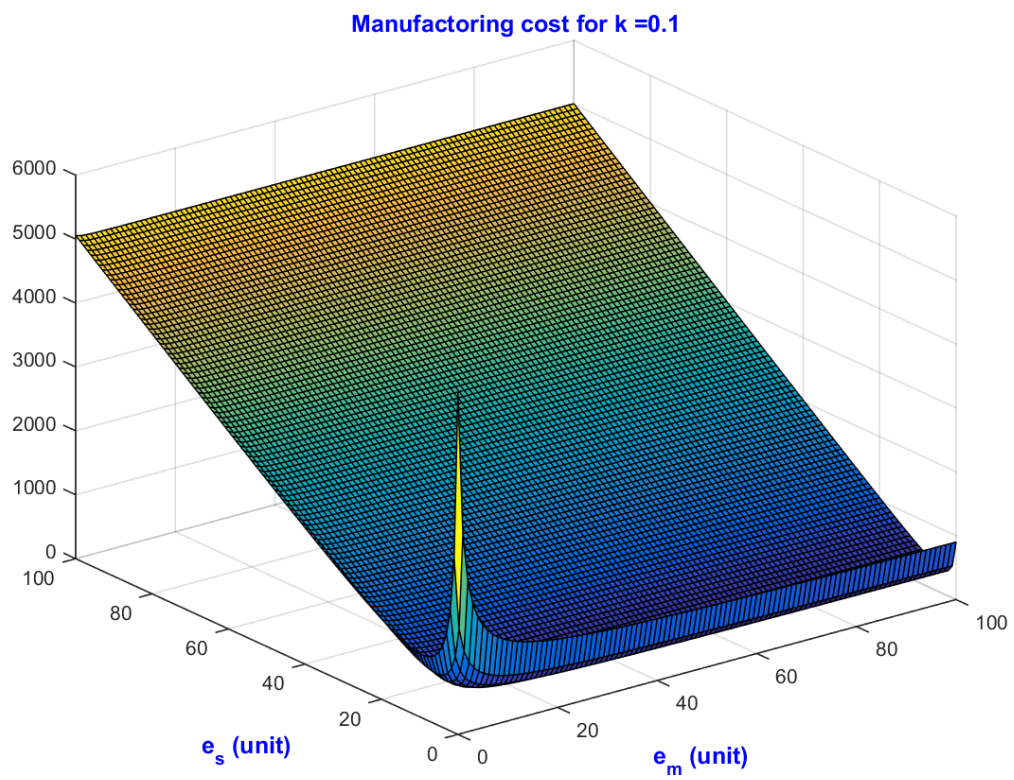
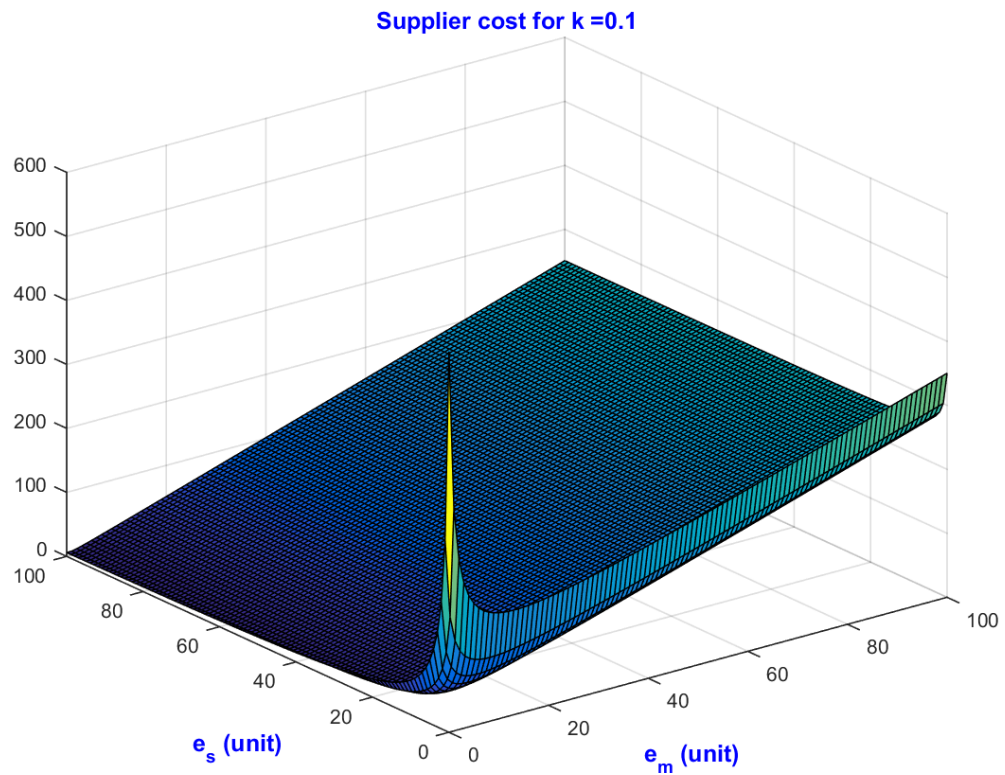


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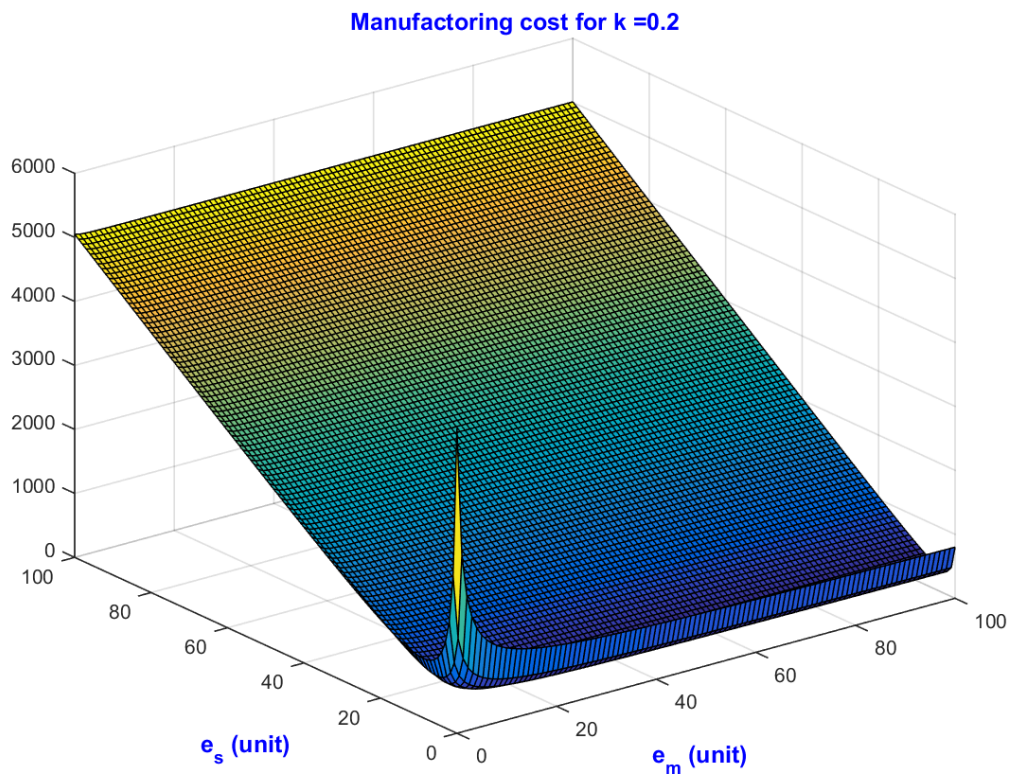
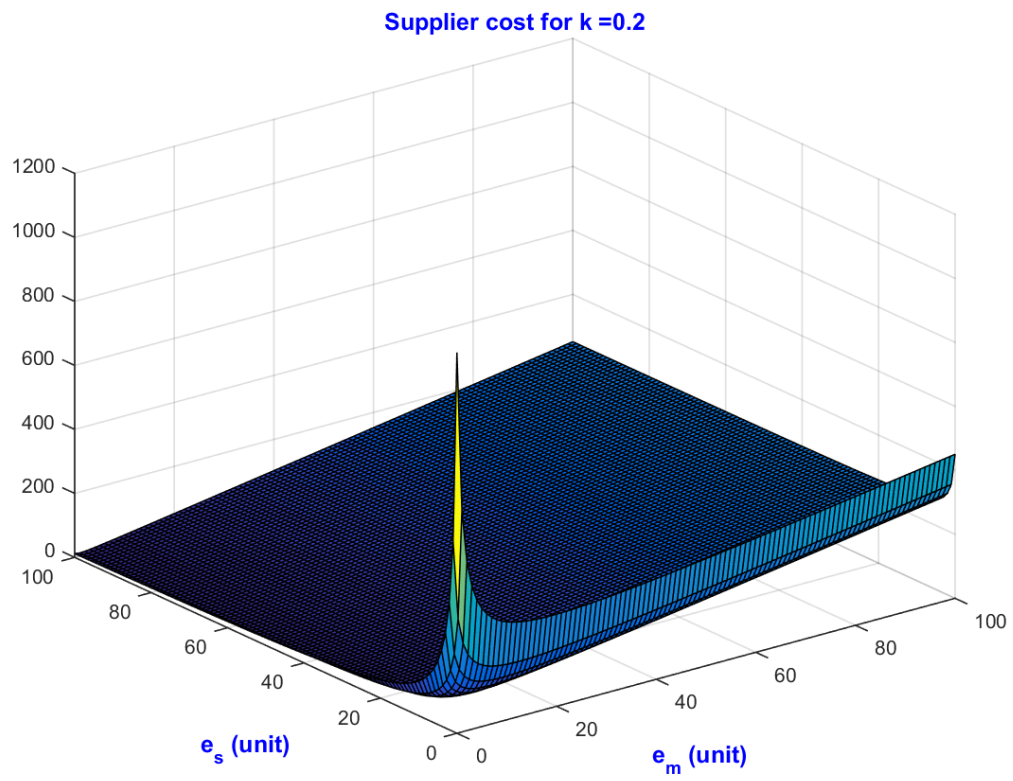


Annex 5 simulation graphic for iPhone 5 case

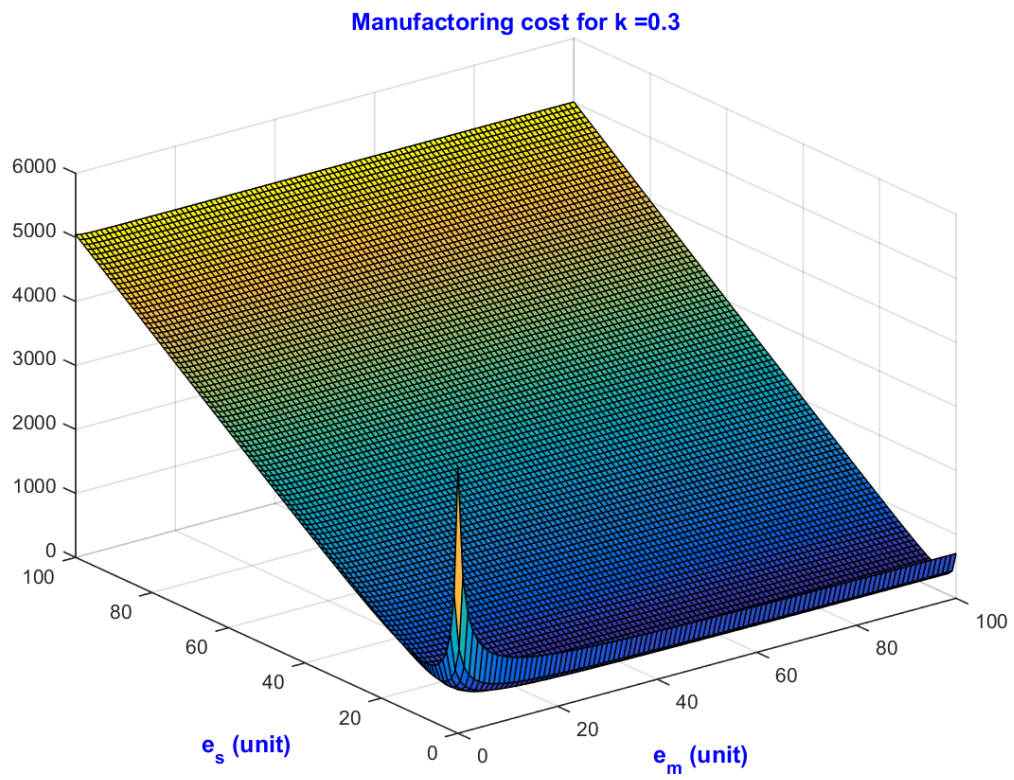
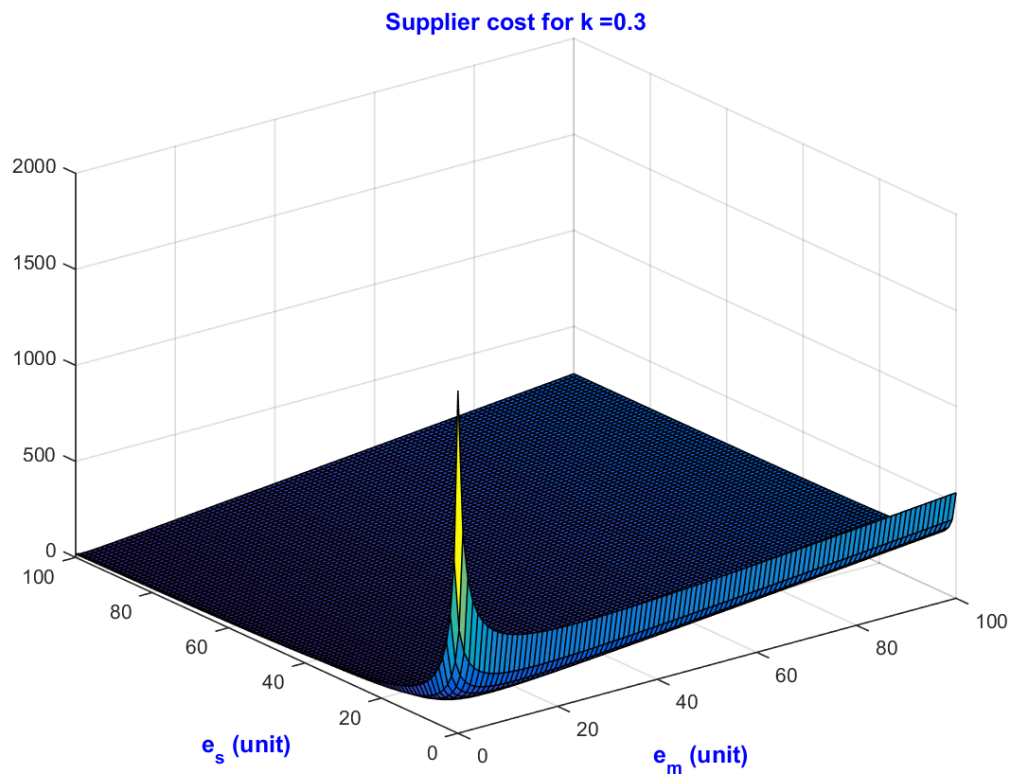
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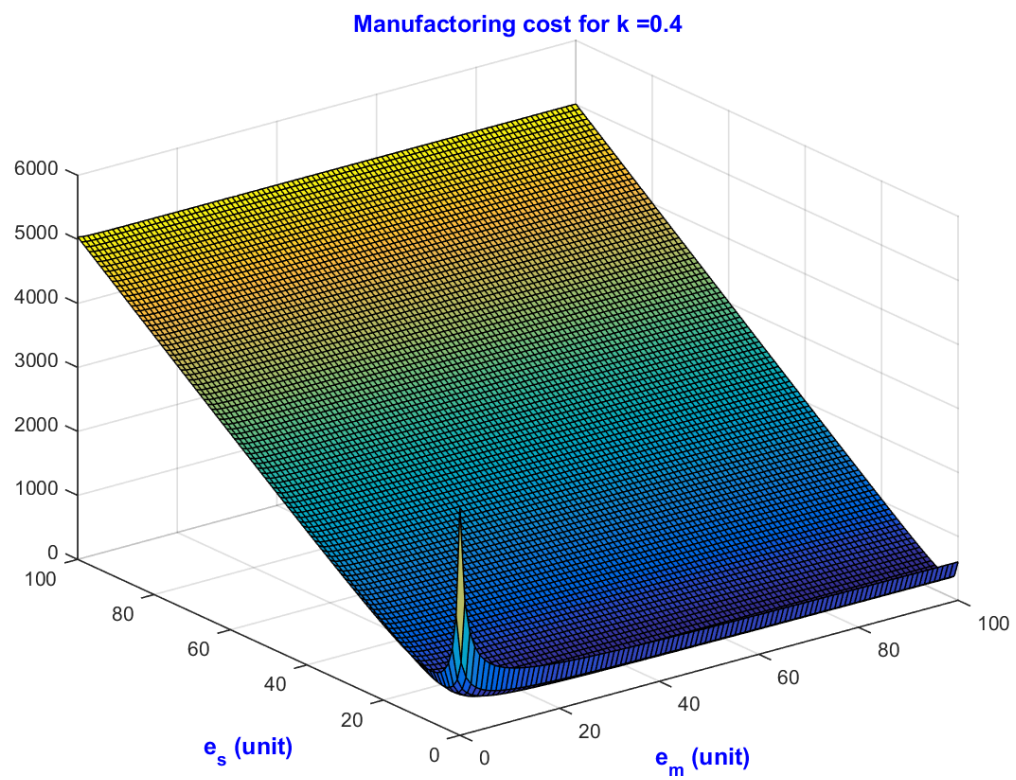
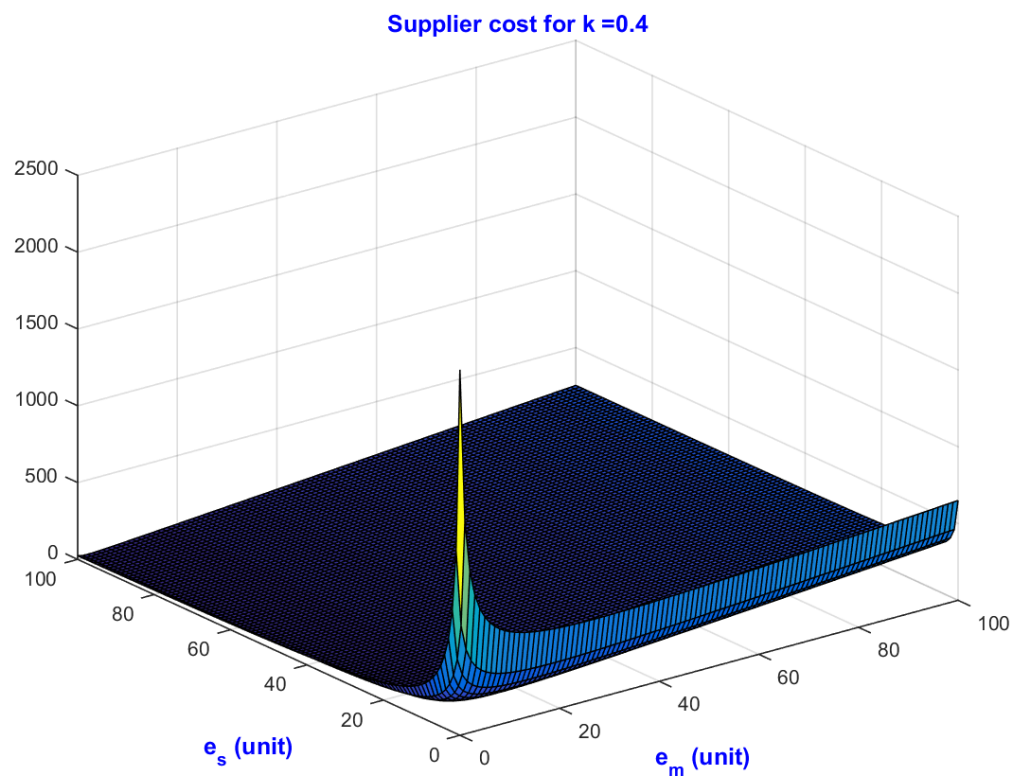
$K=0.2$



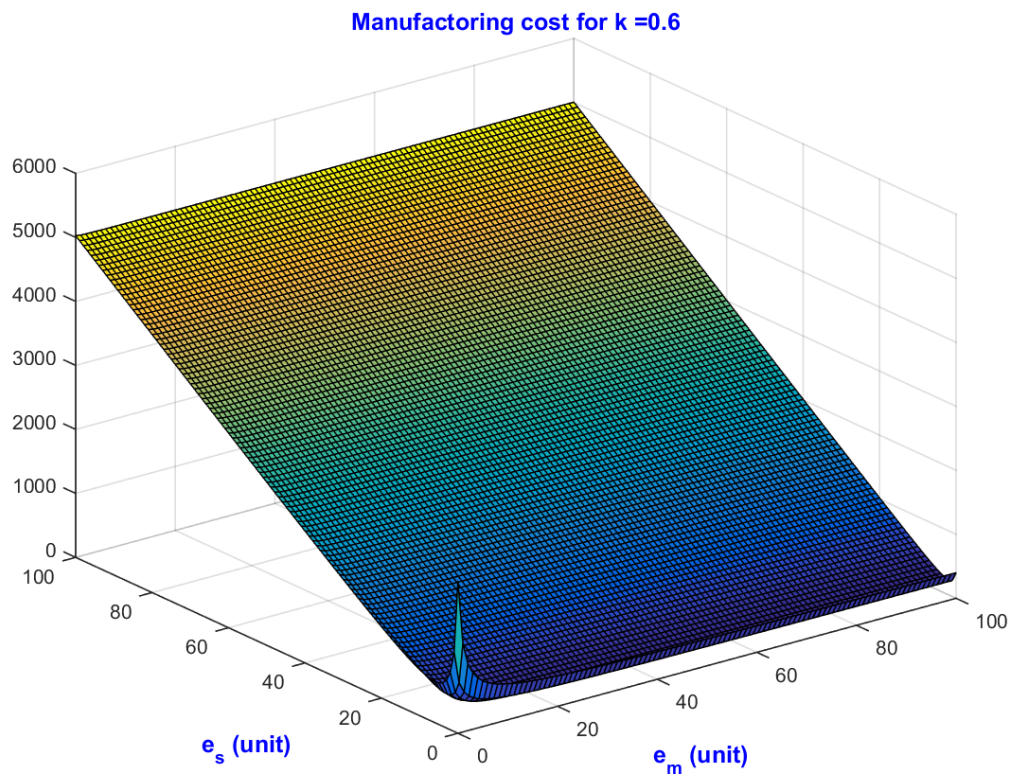
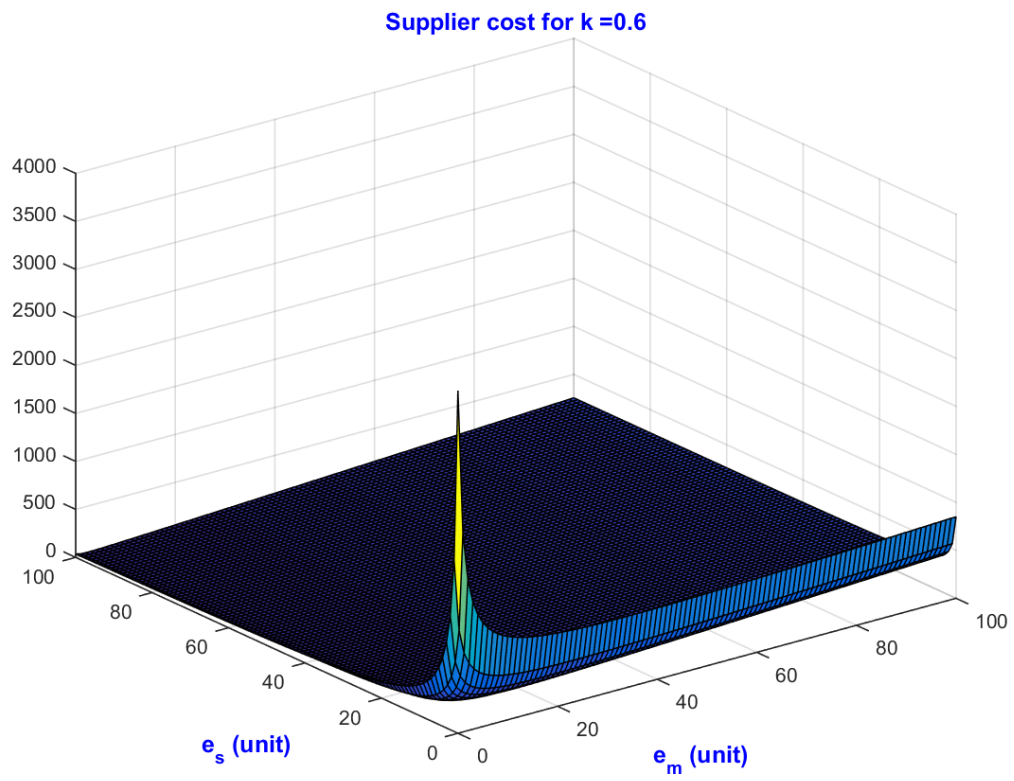
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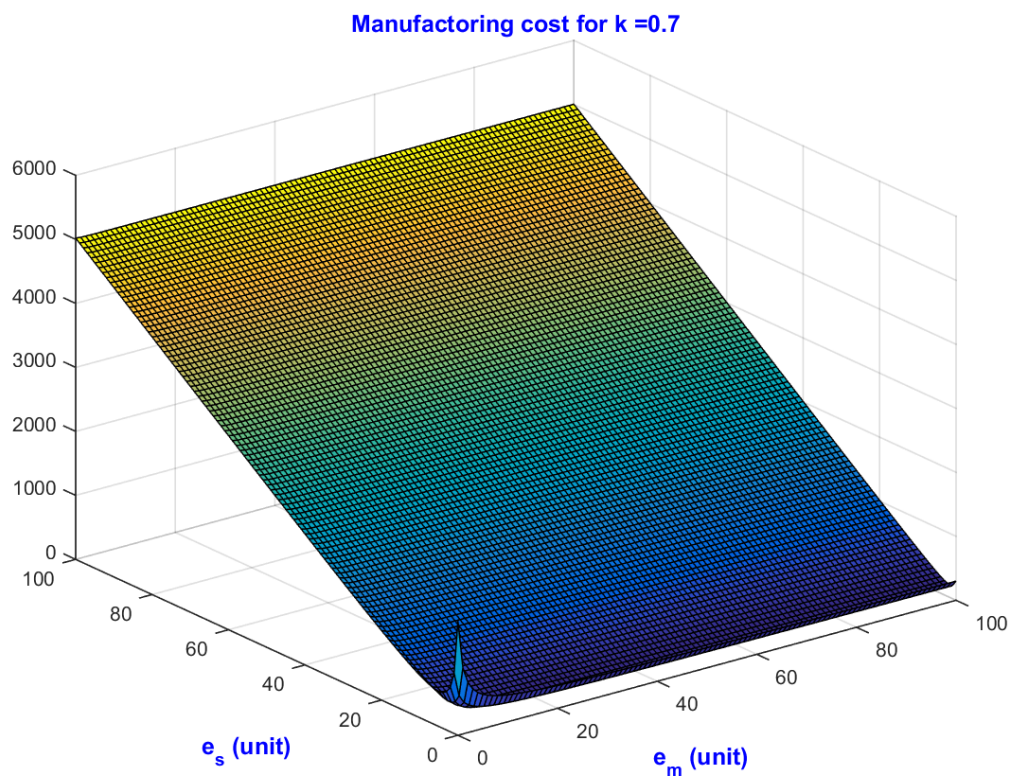
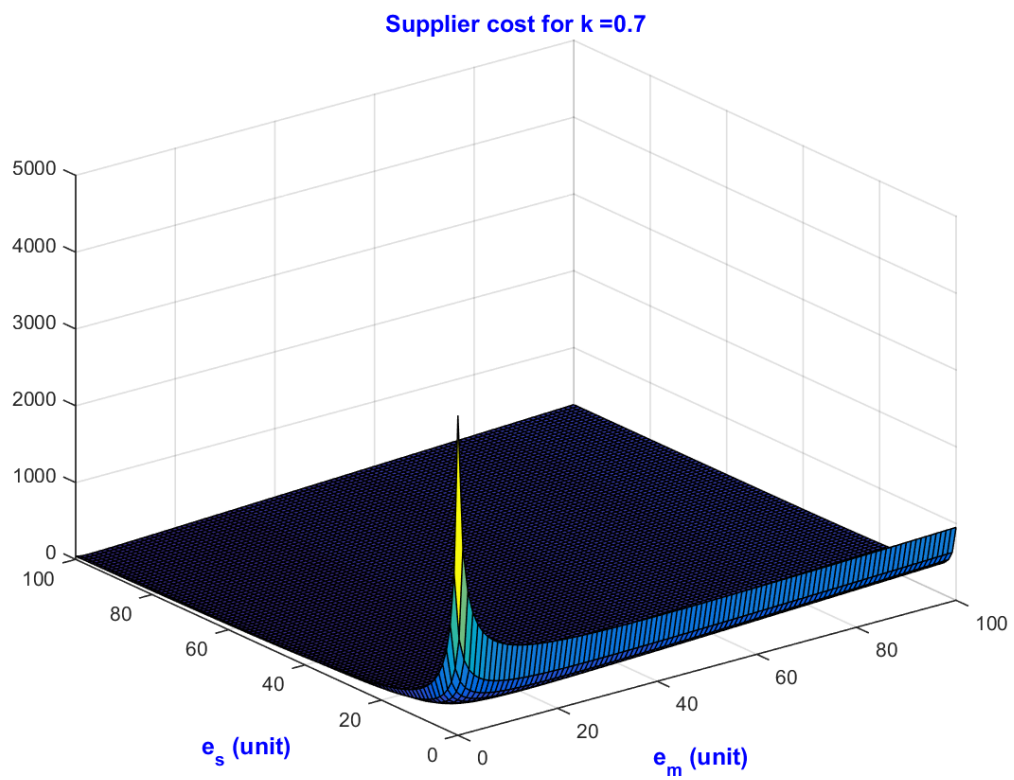
$K=0.4$



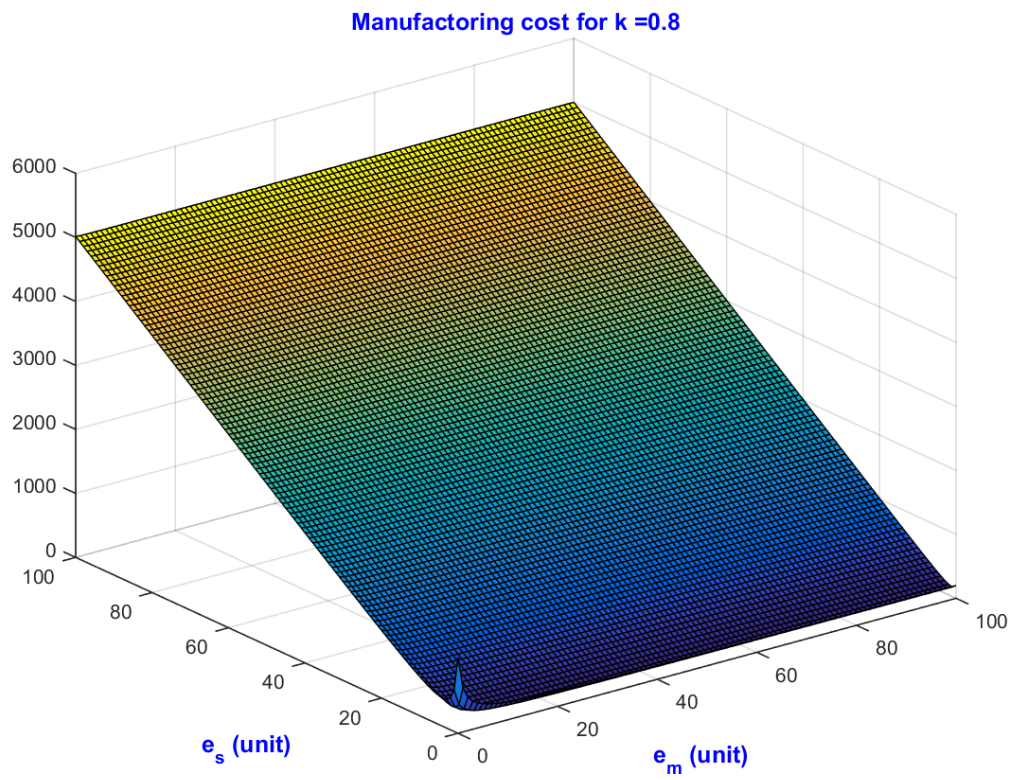
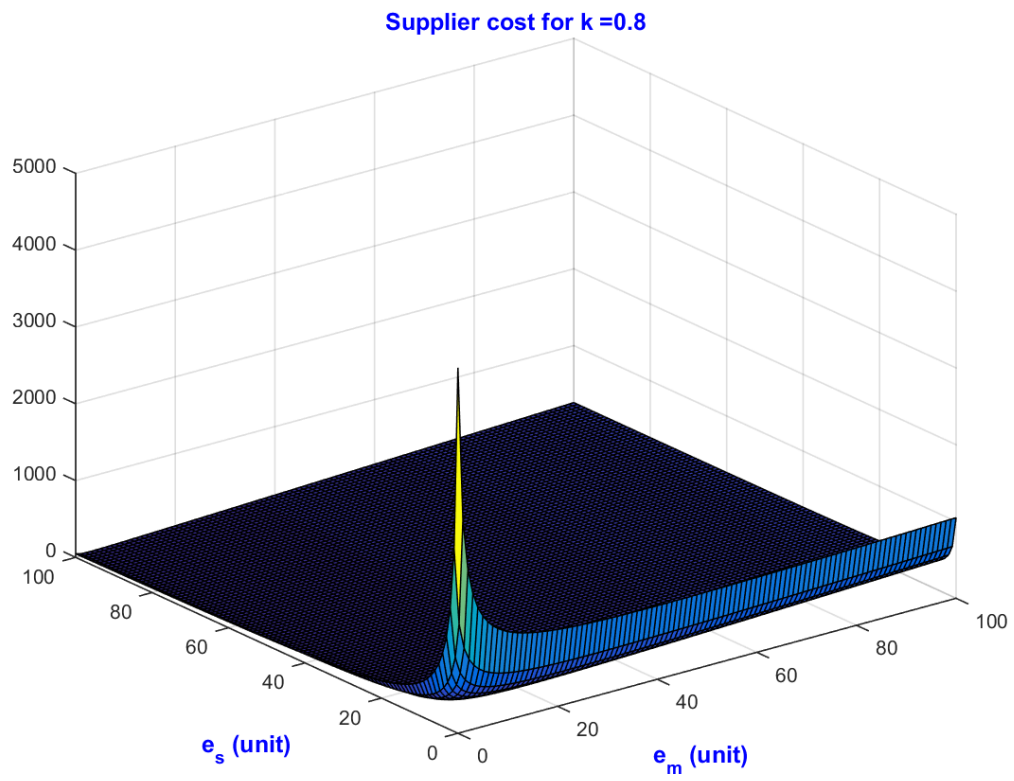
$K=0.6$



$K=0.7$



$K=0.8$



$K=0.9$

